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56th Annual Meeting

AUSTIN, TEXAS, June 14–18, 1948

Host

UNIVERSITY OF TEXAS

Texas—Southwestern Paradox

Cowboys and bucking broncos in an old-time rodeo; beef sizzling over an open barbecue pit; Hereford cattle grazing in the shadow of oil derricks; and a historian on every corner—where else but Texas!

The state with a heart as big as its acres is preparing an old-fashioned welcome for members of the American Society for Engineering Education, June 14–18, when they convene on the University of Texas campus in Austin for their annual meeting.

All the popular vacations are rolled into one in Texas—seashore, mountain, the quaint tinge of the foreign on the threshold of Mexico.

Fired with the spirit of independence which made her the only one of the 48 states to exist as a recognized independent Republic, Texas is a sprawling paradox from the rich and roaring metropolis of Houston to the untamed expanse of the Big Bend Country.

Cosmopolitan Dallas in north central Texas is a recognized fashion and beauty center where "New Looks" often start. Next door in Fort Worth, "Where the West Begins," a cowpuncher stakes his horse to a parking meter, deposits his nickel, and goes about his shopping duties.

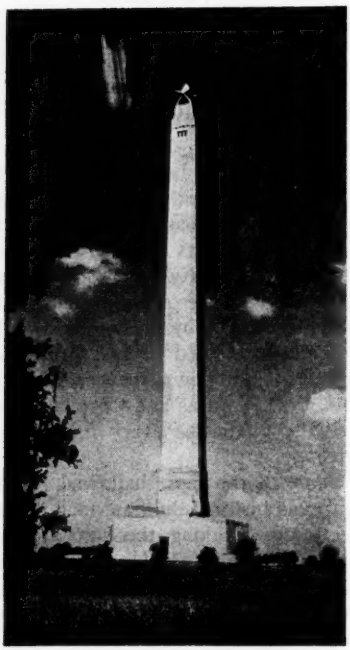
The many and varied resort and historic landmarks in the big state are drawn together in easy accessibility by the network of 25,000 miles of paved highways, numerous airlines and railroads.

For the fishing and swimming enthusiasts, the cool Gulf coast offers miles of sandy beaches, where the waves roll in gently and lap at your toes as you sunbathe, or lick at the side of your boat as you cruise leisurely and try your luck with a rod and reel. Galveston is a resort and commercial center, enhanced by the beauty of palm and oleander lined drives throughout the city. On down the coast, Rockport, Port Aransas and Corpus Christi virtually guarantee every fisherman a catch.

Some of the most hallowed ground in Texas history, the San Jacinto Battleground, is along the ship channel, about 23 miles from Houston and not far from the coast, where the tallest stone monument in the world stands in memory of the heroes of the battle for Texas independence. The 567 foot shaft is topped by a mammoth star, and houses the San Jacinto Museum of History in its base. West of Houston is a large recycling plant at Katy.

The flavor of the old frontier and the wilderness of canyons and coyotes still clings to the Big Bend Country in West Texas. A good day's drive from the convention city (481 miles), it is site of the 707,338 acre Big Bend National Park and boasts some of the most rugged terrain in Texas. The park is only partially developed and is a haven for the hearty soul who likes "roughing it." Additional information is available at the National Park Service, Department of Interior, Washington, D. C., or Big Bend National Park, P.O. Box 251, Marathon.

A stop in the South Plains area's chief marketing and retail center, Lub-



SAN JACINTO MONUMENT

bock, will introduce the traveler to an agricultural area rich in cotton, butter and cheese production. Northward is Canyon in the wheat raising belt, offering, as one of the state's principal scenic spots, Palo Duro Canyon within a 15,000 acre State Park.

The principal North Plains city of Amarillo boasts oil refineries, meat packing, milk product industries and helium plants.

Another side of the state's varied industry can be viewed in East Texas near Lufkin where production of lumber and wood by-products is the chief occupation. Texas' four national forests may be seen in this area.

Visitors who must confine their travels to the immediate vicinity of the convention city will find the gamut of entertainment at their fingertips.

Nestled within a group of purple-hazed hills which have given it the name, "City of the Violet Crown," Austin abounds in good food and good times. The Colorado River cuts its way through the semi-mountains creating a beautiful "palisade" drive along its banks. A 22-mile-long lake provides boating, bathing and fishing. Municipally owned Zilker park with its natural spring pool is one of the many additional swimming facilities.

Four beautiful lakes have been impounded on the Colorado River in the near vicinity of Austin by the Lower Colorado River Authority, and will hold more than mere scenic interest for the fisherman. Their mighty dams, Buchanan, Inks, Mansfield, and Austin, will interest visiting engineers.

In addition to the attractions of the University of Texas where convention sessions will be held, delegates will want to visit the State Capitol, constructed entirely of native Texas granite; the stately colonial style governor's mansion; the Elisabet Ney Studio, home of the world-famous sculptress; Texas Memorial Museum, containing Texas historical, archeological, geological and biological displays; and the O. Henry Museum, containing many things used by the famed short story writer.

Visitors who have a yen to try the life of the "hoss and saddle" will find guest ranches not far from the city where they can join first-hand in ranch life activities.

Trips can be planned out of Austin to one of the many oil fields of the state. Laredo, the chief port of entry to Mexico, is just 231 miles by highway, and entry and departure into

OIL WELLS IN KILGORE

Mexico is easily arranged. Mexican markets, shops and a glimpse at the customs of the Spanish-speaking natives await the visitor who crosses the International Bridge.

For a touch of the Spanish even closer, San Antonio, home of old missions, the Alamo—Shrine of Texas Liberty; and the world renowned "West Point of the Air" is just 76 miles from Austin.

In nearby Round Rock, a 30 minute drive from Austin, the notorious bandit Sam Bass once twirled his "six guns" in flagrant defiance of the young state's law. The little town of Salado, less than an hour's drive beyond Round Rock, is home of the world's only armadillo farm. Here the little armor-clad animals are converted into products for national distribution.

You'll have no trouble getting into Texas and into Austin. Everybody will be "tickled to death" to see you and you'll find rail, bus, and airline service to the steps of the convention site.

Missouri-Kansas-Texas Railway serves Austin through the "Texas Special," and Missouri Pacific Railway through the "Sunshine Special," both of which offer 22-hour service from St. Louis and a 45-hour service from New York City. The Missouri Pacific is planning to add a special train which will meet trains from Chi-

PORT ARTHUR-ORANGE BRIDGE

cago and the East at St. Louis and will cut five hours off the usual running time, to arrive in Austin at 10:30 A.M., Monday morning, thereby making it possible to attend Monday afternoon sessions. Southern Pacific Lines are ready to take you to all Southern, Western and Eastern points.

Several air lines service the city and Southwestern Greyhound Lines, Inc., Bowen Motor Coaches and Kerrville Bus Co., Inc., furnish adequate motor-bus and motor-freight transportation in all directions.

Housing accommodations are available in five Austin hotels with a total of 875 rooms where rates range from $1.50 to $2.50 and up for single rooms, and $2.50 to $4 and up for double rooms. Thirty-six tourist courts, nine or more including kitchenettes, offer additional facilities.

SHRINE OF TEXAS LIBERTY,
THE ALAMO, SAN ANTONIO

THE STATE CAPITOL, CONSTRUCTED OF NATIVE GRANITE. IN THE BACKGROUND IS THE TOWER OF THE UNIVERSITY OF TEXAS' MAIN BUILDING

The exacting gourmet is invited to tickle his palate with crisp, southern fried chicken, a steaming, thick Texas steak, or the unique Spanish-style cooking of Austin's many fine restaurants.

A vacation to Texas doesn't need to be expensive, for there is no full scale, commercialized tourist air about the state's scenic wonders. A uniformed tour guide won't approach you hawking his wares as a quick swing around the country for a maximum fee.

Yours will be the unhurried, homey hospitality which invites, "Come on in and set a spell."

Business Management of a College Research Laboratory*

By R. A. HUSSEY

Professor of Industrial Engineering and Business Manager, Ordnance Research Laboratory, The Pennsylvania State College

The administration of a College research laboratory involves two distinct and related responsibilities which must be properly balanced for successful operations. The research division is established to provide a distinct service for its sponsoring agency. The director becomes the trustee of this agency and is burdened with the responsibility of directing the research program successfully and to the financial satisfaction of the sponsor. Most sponsors insist upon good business methods and research itself benefits through such operations.

Sound business methods insure the good will of the sponsor and consequently the probable continuation of the program. They provide the materials and services needed with a minimum of delay. They maintain effective working conditions and provide many other services which must be provided to keep the scientist "happy and contented." (The happy and contented scientist is after all the most effective one.)

The administration of a college research laboratory is usually vested in a director whose background, training and tendencies are primarily "research." This by no means infers that research directors are not good business men. The center of their interests is naturally in the intricate and puzzling problems with which they are challenged in their own field. Business methods have become well standardized and consequently the business operations are usually delegated to a business section, the leader of which is directly responsible to the director. The aim of the business manager, naturally, is to satisfy the needs of the research scientist within the possibilities established under the terms of the research contract.

The task of the business manager is difficult because of the manner in which research scientists must operate. The principal aim of research scientists, and justifiably so, is to arrive at a satisfactory solution to their immediate problem subordinating all other considerations. They are rather impatient souls and undoubtedly their effectiveness is handicapped if the facilities, materials and manpower are not immediately available for the work at hand.

While not a serious indictment of researchers most of them are allergic to the usual run of controls established by scientific study for effective operations. These control features consume their time and interrupt the very necessary

* Presented at the Allegheny Section Meeting of the A.S.E.E., Pennsylvania State College, October, 1947.

train of thought. Time is of utmost importance; costs are easily justified if the test is successful and cause no great concern as long as something definite has been determined.

On the other side of the management picture is the sponsor of the program looking for full justification of its financial support. While the business manager is not directly concerned with the ultimate product of the laboratory he is greatly concerned with the problem of disbursing the funds in a manner acceptable to the sponsor.

The business manager is literally in the "middle." On the one side is the need for maintaining, within his power, the highest morale of the scientists and on the other side the control of expenditures to the complete satisfaction of the sponsoring agency. The more difficult problem is the former. It has been stated that "the employee becomes more discontent with the manner in which he is supervised or managed than he does with wages, hours of work or working conditions." This, I think, is more especially true with the research scientist. It is not so much what you do to him but the manner in which you do it.

In dealing with research scientists in general no standard plan of procedure is applicable to all situations and seldom is it possible to apply the same method of solution to identical problems involving different groups of research scientists. Each case merits its own study and the application of a particular method of approach. Psychology would appear to be the answer to most management problems involving scientists, and the lack of some understanding of human behavior will make the path of the business manager extremely toilsome.

Research seldom pays immediate dividends and very often dividends are forthcoming only after great expenditures of time and money. Agencies which finance research are usually cognizant of these facts and are most patient in their attitude toward the manner and amount of expenditure. It is quite generally accepted that research succeeds in the long run and little difficulty is experienced by the business manager in the financial affairs as long as there is no wilful waste and an honest effort is made to use available funds to good advantage. Successful business management in a College research organization can thus be measured by the sum total of the effectiveness of its program in doing its proper share in maintaining a contented and consequently highly effective research force and in satisfying the sponsoring agency that its funds are being properly handled.

The proper disbursement of funds necessarily requires detailed recordings involving the activities of each and every member of any organization. The complete satisfaction of the sponsoring agency can be obtained only through the cooperative effort of the research and business organizations.

It thus becomes apparent that the organization of the business division of a research laboratory is vitally important for successful operations. The foremost consideration in organizing a business division of a research laboratory is personnel selection. People with a full understanding and appreciation of the human problems involved should be selected for the necessary positions. Persons steeped in the modern practices of industrial or commercial operations may become the problem children in the research organization if they are not immediately susceptible to a most liberal education. The only other solution is a painful readjustment of the

organization which can easily lead to a complete lack of confidence in and general breakdown of the business organization.

The business division of a research laboratory is responsible for many services to the organization as a whole and to its administrators. Many factors control the scope of services to be provided. A full measure of service must be provided if the laboratory is self-contained and the services of a non-technical nature are divorced from the research activities.

The trend seems to be toward self-containment leaving the research personnel free to concentrate upon technical problems. It may be financially necessary to compromise this situation through planned operations by the business and technical services.

The geographical location of the laboratory definitely affects the organization of the business division. Transportation, comunications, nearness to markets, etc., must be given due consideration. The more isolated the community the greater the demands for service. Serious study should be made of these factors in their relation to possible needs.

The only general assumption possible is that the business division must provide such services as are necessary to successful operations under the particular circumstances in which the organization as a whole will function.

These services may be generally classified as follows:

1. Procurement
2. Financial
3. Maintenance
4. Transportation
5. Communications

The order of classification does not necessarily indicate degree of importance; they are all of vital importance and circumstances determine the extent to which each of these services must be provided. The financial arrangements with the sponsor may limit or even prohibit certain desirable services.

Procurement for a research laboratory is a highly specialized task; the type of work to be accomplished necessarily makes it such. The research program does not call for any large volume of any particular item or material, nor does this material even approximate the usual industrial raw material. Requirements are highly diversified and often quite specialized and more often than not the materials required are the most difficult to obtain. The quantity needed is usually so small that special efforts must be made to procure it.

The Purchasing Agent must be thoroughly familiar with the items generally allied with the research program and especially with the various sources of supply in order to expedite their procurement. The scientist usually wants what he wants immediately—or sooner, even if it isn't possible to get it. It is very difficult to offer a valid excuse for failure to procure, and in research substitutes more often will not suffice. Every means possible must be made to obtain the desired items and it is usually to the adavntage of the program to procure and then explain. Short cuts in the purchasing procedure may, at times, be necessary to facilitate procurement of some vital piece of material. For these reasons, the Procurement Division of the laboratory should be entirely divorced from the general or centralized purchasing function of the College or parent institution which is usually steeped in a tradition of routine.

Purchasing is but the first step in an adequate procurement program. The

personal knowledge of the Purchasing Agent must be fortified with an adequate library of catalogs and a current file must be maintained of all possible sources of thousands of standard as well as highly specialized items of material and supplies. The research personnel obtains a wealth of knowledge in new ideas and new applications from vendor's catalogs and scientific data sheets. Personal contacts by the Purchasing Agent and his distribution of good will can never fail to benefit.

Orderly and properly controlled storage is necessary for the more commonly used materials and supplies to cushion the needs of the technical as well as the non-technical services against the uncertainty of present procurement conditions. Purchased items must be checked for acceptable use and then find their places in a properly identified, easily accessible, and safe storage. Storerooms should be specialized if space, manpower and demand are sufficient. Storerooms should be adequately manned to handle and record receipts and issuances and to operate the controls necessary to insure a supply adequate to meet the demands at all times.

The necessity of the purchase and the reason for placing the order with a particular supplier appears to be of special interest to the financial sponsor. The auditor will frequently inquire about many of the purchases and adequate substantiating data should be filed with the copies of each purchase order showing the various bids received, the approval for the purchase and any particular reason for selecting a given vendor, all things being equal.

The final responsibility for procurement is not relinquished by the Purchasing Agent until the vendor's invoice has been checked for receipt and acceptability of goods, for price, for discount, and the purchasing records involved have been filed in an orderly manner to provide for future use in case of question.

The financial section is concerned generally with the accounting for and disbursement of funds made available under the budget as provided by the administration and accepted by the sponsors. Budget estimates should be provided by project leaders in the technical divisions for the funds necessary to carry on the work of their task assignments. These estimates should be checked and revised by the administration and become the basis of the periodic request for funds.

For adequate control of expenditures monthly budgets should be prepared for each project against which the actual costs of operations may be measured. The purpose of properly costing the various projects is not to evaluate the results of a particular research problem, but more as a guide to future action and control of expenditures within reasonable bounds. Many discoveries or developments in research are worth infinitely more than was ever put into them in cash while others necessitate large expenditures to discover the futility of a certain approach. Only through the monthly budget and financial statements is it possible to plot a sound financial path leading successfully to the end of the fiscal year.

The head accountant is responsible for the detailed accounting and recording of all disbursements to the satisfaction of the auditors. Vendors' invoices must be checked for correctness, properly coded for classification, recorded, and approved for payment.

Payrolls must be executed on the basis of accurately reported times in the case of wage earners, and salary rec-

ords maintained for the issuance of salary payrolls

A plant ledger of all capital items must be maintained according to the requirements of the sponsors. This procedure usually requires the complete identification of each item of capital equipment and periodic, usually an annual, physical inventory and report to auditors indicating additions and disposals over the period.

Petty cash funds are usually established under the control of the head accountant to facilitate the quick purchase locally of necessary items. The importance of readily available and substantial petty cash funds cannot be overemphasized in the research institution. Adequate controls over the use of these funds may be effected by authorizing division heads or project leaders to approve such purchases.

Monthly financial statements should be prepared for the sponsors as well as for the administrators of the laboratory. The extent and form of such statements will vary according to the demands of the sponsor. The minimum requirements would appear to be a Statement of Expenditures for the current month, a Statement of Expenditures for the year to date, both according to class of expenditure, and by project, if required, a Budget for the succeeding month and a Summary of Contract Expenditures to date.

Adequate files of all supporting data, such as approved copies of invoices, the up-to-date schedule of approved salaries and wages, time reports, etc., must be maintained for the auditor's ready access.

Filing space requirements for the procurement and financial sections may become a very serious problem over a period of time and should be well considered. The only alternative would be the utilization of some space reducing instrument such as the 16 mm. film and enlarging projector.

In the self-contained and self-housed research laboratory, maintenance becomes a major problem and greatly diversified in its requirements. Most such laboratories are equipped with highly specialized precision tools and electrical apparatus. The maintenance problem involves not only the proper care of machines and apparatus to insure their full use at all times, but also the necessity of removing and relocating such equipment and making minor additions.

An adequate electrical maintenance force must be maintained to make new installations, to service existing equipment and to provide for the best possible service from the lighting system. A uniform and adequate source of artificial lighting is unquestionably of vital importance in a research laboratory, and a definite program for the orderly maintenance of the lighting equipment is a high priority requirement.

Mechanical repairs to machinery, equipment, and the proper operation of the heating and ventilation systems could well be placed under the direct supervision of a skilled millwright. As in the case of electrical maintenance, this program of mechanical maintenance should be one of planned maintenance to insure continued operations. The only delays in operation should be those which could not be foreseen through periodic inspections. Expenditures for preventive maintenance pay dividends in increased output.

The janitorial force requirements for such a laboratory is considerably greater per square foot of floor area than for most of our industrial installations. It is probably greater than

most of our College building requirements. Considerable pride exists among research personnel in the appearance of their work shop. Dirt and dust handicap the research worker. Many of the operations must be dust proof. Most laboratories are designed to obtain the best possible use of natural lighting and constant attention is necessary to provide full use at all times of this natural lighting.

Protection of the physical property against fire is a serious problem. Many types of fire may originate in the highly diversified operations carried on. Means must be taken to combat these various types of fire. Water hose, fog nozzles, extinguishers of various types should be placed in strategic areas with proper instructions for use. Certain of the personnel should be thoroughly instructed in the types of extinguishers to use under particular conditions and periodic testing of such fire fighting apparatus should be made by the maintenance division.

A building security force may be necessary according to the requirements of the sponsors. This force may be maintained only to protect the property against fire and physical damage, or it may be further obligated to the protection of classified operations against unauthorized visitors. In the latter case particular attention must be given to the personal quilifications and training of the members of the force.

The Maintenance Department should be under the supervision of a highly qualified individual familiar with building construction and installation. His responsibilities are many, requiring not only the coordination of his own activities, but also the planning of his work to suit the convenience of the research personnel whenever possible. His work is purely of a service nature demanding patience, perseverance, and the ability and will to cooperate.

Many research programs require a considerable amount of travel. Research personnel are required to visit allied laboratores, field stations, and manfacturers. Members of the administration must confer with the technical personnel of the sponsor. Business operations necessitate travel in the interests of the laboratory. Generally the travel expenditure is large and many cities are visited and many types of transportation are utilized. Air travel is the miser of time and greatly appreciated by the research man. Hotel and pullman reservations must be obtained with a minimum of advance notice. Cancellations must be made as painlessly as possible. A Travel Office should be established to centralize, coordinate and control all travel requirements. The contacts made by a capable Travel Clerk soon pay dividends in obtaining satisfactory travel accomodations by air, train or in hotels. Everything possible should be done to make travel convenient and as comfortable as possible for the research man—his travel is usually at night after a hard day at his desk or bench. A travel policy should be established by the administration to facilitate control and eliminate duplication of effort which can rapidly increase travel costs.

A revolving travel fund should be established under the control of the head accountant and administered by the Travel Clerk to provide advances for laboratory travel. Adequate approvals and controls should be established to utilize this fund to the best advantage. Travel aids such as credit cards reduce the necessary size of the fund. Whatever can be done for the convenience of the research traveler will be repaid.

Local transportation may best be provided by laboratory owned vehicles. This arrangement naturally depends upon the locality and local conditions. If vehicles are maintained the Travel Office is the logical control point to schedule their use to the best advantage of all concerned.

Last but not least in importance is the system of communications. Any adequate system of communications in a self-contained research laboratory of sufficient size should consist of a central switchboard with adequate outside cable connections and inside extensions to care for the volume of business necessary, and an efficient mailing and messenger service.

Telephones should be generously allotted to the various work places of the laboratory personnel and grouped by wiring plans to facilitate their use by group secretaries. Installation and monthly rental costs of such extensions are insignificant in comparison with the satisfaction gained through the immediate availability of a telephone and speedy service to the outside world.

Experience with a laboratory carrying on classified operations has emphasized the necessity of a central mailing and messenger service. Postage costs are unusually high in proportion to number of pieces mailed. There is a problem not only of proper usage of postage but also of proper classification and the application of the exact amount. To give any semblance of control over wasteful and illegitimate use postage should be purchased by one person and requisitioned for use as needed by the postal clerk. If the mail volume is sufficient a postage meter is naturally the answer to postage control and also provides a more complete mailing record.

This rather brief outline of the business function of a research laboratory covers only the most important services for which the business manager is responsible. Such an organization of the pertinent services may appear to leave little to be done by the business manager.

Many are the unusual and debatable points arising in the every day operations of the business division and it is the personal responsibility of the business manager to resolve these differences without recourse to the administration except as a court of last resort.

Personnel problems arise in the business organization as in other organizations, and differences develop between the business and scientific groups which must be solved to the mutual satisfaction of all concerned. Varied are the human traits to be dealt with in supervising an organization which must coordinate its services with those of such a highly specialized and professional group as research scientists.

Goods cannot be dumped on this market. Cooperation varies directly as to the benefits received. Only through a constant search for better ways to provide these services can the business division survive the natural growth of progress.

The Organization of a Research Laboratory*

By ERIC A. WALKER

Director Ordnance Research Laboratory, The Pennsylvania State College

Introduction

No type of business has grown faster than research has during the recent war, and the climax to a whole series of inventions was dramatically supplied by the atomic bomb. Today the word *research* is a household word, and almost everyone expects it to bring forth wonders like the rubbing of Aladdin's lamp. Some idea of that growth can be obtained from Table 1.

The scarcity of skilled scientists[1] in many fields is well known and has been fully discussed.[2] This scarcity is being accentuated by the desire of many industrial concerns to establish research laboratories and the need of colleges to refurnish and augment their research and teaching staffs. Yet many institutions inaugurating research programs may well waste the efforts of skilled scientists unless adequate facilities are supplied and proper administration is provided. This is not an easy task, since so little information is recorded on the organization of research geared to peacetime needs. It was possible to organize research workers effectively during the war but this does not insure an effective organization in peacetime; for scientists, like most other individuals, realized the importance and urgency of their wartime tasks and were quite willing to serve as good soldiers so long as the emergency lasted. Now, however, many of them seek the kind of life they believe peace should afford, and unless a proper atmosphere is created, the efforts of many may be wasted.

There are three major problems in organizing a laboratory: first, to create a proper atmosphere for research; second, to provide proper physical facilities; and third, to utilize and disseminate the results of research.

The Research Atmosphere

In order to be productive, scientists, like other workers, must be relatively happy and contented both in their work and at home. This does not require a high rate of pay alone. Indeed, if anything, this is far from a major consideration, as the important work done by the poorly paid scientists in the laboratories of our schools and colleges will testify. In such places the scientists are much underpaid, at least by industrial standards; yet their work goes on because of other factors which contribute to the research atmosphere. However, just because a scientist will work for a relatively small remuneration, he should not be required to do so. The employer for his own good should pay his scientists enough to relieve them of worry about the maintenance of their families and to insure them a comfortable old age when they retire.

Some thought should be given to the location in which the scientist wants

* Presented at the Allegheny Section Meeting of the A.S.E.E., October, 1947.

TABLE 1

GROWTH OF RESEARCH IN THE PAST TWENTY-FIVE YEARS

Year	Number of Industrial Research Laboratories	National Income $	Funds for Industrial Research $	Funds for Government Research $
1920	300	74.10^9	29.10^6	15.10^6
1930	—	77.10^9	116.10^6	24.10^6
1940	2200	77.10^9	234.10^6	69.10^6
1944	2500	160.10^9	300.10^6	719.10^6

to work and live. This problem can best be solved by considering the hobbies, avocations, and amusements to which scientists resort in their leisure hours. Contrary to the popular notion, the average scientist is a gregarious sort of person. His hobbies may often cover a wide range of interests, such as music, fishing, golf, and painting. Such avocations require a combination of both urban and country living conditions. This situation is realized when a corporation locates its research laboratories in a relatively undeveloped section of the country but one within a few miles of a main communication line to a large urban center. This is but one consideration—a geographic one—and little more can be said, for despite the large amount of investigation which has gone into devising means for selecting good soldiers, good medical students, good engineers, etc., and despite the research into the mind and psyche of every class from alcoholics to Zarathustrians, virtually nothing has been done to discover just how a good research scientist gets that way. Until this is done, intuitive measures must be used. Thus one is lead to a consideration of the immediate working facilities and circumstances.

THE RESEARCH FACILITIES [3, 4, 5]

The laboratory building deserves to be a modern one with all the conveniences modern design can provide. The scientist does not by choice do his work in an attic, dark basement, or a shed. To ask him to do so not only insults his intelligence but reduces his efficiency. The scientist, just as much as any businessman, deserves a comfortable office in which he can do his thinking and writing and in which he can receive callers with a feeling of pride. His laboratory, too, should be one he is proud to exhibit, although it may not look like a showpiece to one unfamiliar with the scientist's work and therefore to one unable to perceive any system in the apparent disorder.

In considering the facilities which one provides for a scientist, one must regard him as a machine and an expensive one at that. It can be shown that the average scientist costs his employer more than $10,000 per year.[6, 7] This includes his salary and the things which must be provided for him to do effective work. One might amortize this scientist on a ten-year basis and say, therefore, that he represents a machine worth approximately $100,000. A wise manager thinks twice before allowing such a machine to remain idle or to be used for a purpose for which it was not intended. A wise manager, then, should think twice before allowing a scientist to be idle because some facility is not at hand or because some component, some data,

or some service cannot be provided. He also should think twice before allowing a scientist to do tasks for which he is not fitted and which someone else can do better, such as performing business operations, cleaning up, soldering joints, operating a lathe, writing reports, typing, etc.

Thus, a major factor in creating a research atmosphere is one of management wherein the scientist must be relieved of all petty worries and of all those functions at which he will work inefficiently. It goes without saying that the scientist should be completely isolated from the advertising department, the sales department, the business offices, and such. Business offices can do a great deal of damage and even destroy a research atmosphere by indulging in what the scientists consider annoyances about petty details. When asked to list the things which annoy them most, scientists show a striking tendency to worry about details. In particular, one scientist has spent a great deal of time bemoaning a charge of 26 cents in an expense account because of his failure to present a tax exemption certificate. Indeed, by now that 26 cents has cost the company hundreds of times as much as if it had been forgotten in the first place. Other scientists will complain about the red tape necessary to obtain inconsequential supplies or a requirement to present a receipt before being reimbursed for some stuff picked up at the dime store. A wise business office will avoid such items when dealing with men who are important cogs in the laboratory's machinery.

On the other hand scientists themselves show a remarkable propensity for wanting to do little things themselves, if these are of their own choosing. Then they must be reminded that their time is too valuable to be spent on such details. They should not be asked nor allowed to stand in line to buy railway tickets or to make out requisition forms after digging through complicated catalog numbers or to sign receipts in triplicate or to write out reports in longhand or to walk to a library to obtain a copy of a well-known book. The laboratory can well afford to supply such services to its better and more expensive men.

Great care must be taken in planning the machine shop facilities. A scientist prefers to perform minor mechanical operations himself instead of asking someone else to do it. He would much rather drill a hole or solder a connection than write an order for the shop to do it. On the other hand, few scientists are competent to operate expensive machinery or to perform a mechanical construction to close tolerances. This problem can best be met by providing two shops, one equipped with simple and inexpensive tools to which any scientist has access without notice and in which he can do simple jobs himself. For the more important jobs, a complete machine shop must be provided with two methods for requesting work. If the development of a particular device is only in the breadboard stage, sketches alone are sufficient for machine shop directions. If, however, the device is in the prototype stage or is very complicated, then a full and complete set of the prints and specifications are necessary. In the first instance the sketch may be supplemented by oral instructions to the shop foreman but in the latter the written material must stand alone. By making all parts to the specifications and by introducing changes simultaneously in the model and in the drawings, an up-to-date history of the

development is assured. Such organization, of course, presupposes the existence of a well-equipped design and drafting department capable of putting a design into a form which can be used by any competent manufacturer.

The Research Organization

The technical organization of the laboratory is often a stumbling block, for scientists are jealous of their scientific freedom and rightfully so. They resent any insistent direction especially when it is delivered through obvious channels. Yet left to himself, the average scientist might wander from one problem to another never producing usable results. Such behavior can be condoned only from a few unusual men who, through uncommon gifts, can plot their own courses and follow them to a successful conclusion. The average scientist, because of limited information and poor perspective, is often unable to choose the particular field or line of research which will be most profitable for his employer.

The type of scientific organization for a research laboratory is determined to a considerable extent by the size of the laboratory or, more properly, the number of scientists employed. The smaller the organization, the fewer rules, regulations, procedures, and controls necessary to keep the laboratory operating effectively. Indeed, if one extrapolates this simplicity to a single scientist working in his own laboratory, few and only self-imposed rules are necessary.

An advantage of a small laboratory is that it is not necessary to formulate rules and restrictions for men who can be trusted in order to circumscribe the few who cannot be. In a small laboratory a great deal of collaboration can be assured by personal contact. There can be a free interchange of scientific ideas without wasting time. Further, there can be some interchange of administrative ideas also. Thus, a discriminating executive can choose those rules and regulations best suited to his particular type and size of laboratory.

Another factor determining the organization plan of a laboratory is the breadth of technical work. Suppose, for instance, the laboratory confines its activities to research in one single scientific field, such as acoustics. Certainly then little organization is required. If, however, the laboratory includes a mechanics division, which must include aero- and hydromechanics, an electrical division, a mathematics division, an acoustics division, an optics division, and a thermodynamics division, the work of these different groups is usually well enough separated so that each group needs its own group, section, or department leader. Then a major problem for the executive is to get a free interchange of information between the groups. This can be done by routine media such as reports, memoranda, conferences, and administrative committees. However, they all take time and tend to reduce the efficiency of the laboratory.

Another factor in determining the organization of the laboratory is the type of task undertaken. It may well be that a laboratory includes all of the physical sciences mentioned above, but most of its projects cover only one or two of these sciences. For instance, the design of a microphone will not necessarily involve any work on the part of the mechanics, optics, or thermodynamics departments; but if the laboratory should undertake the design of an entire system, such as a blind

landing system for aircraft, it may well be that all sections must contribute experimentation and construction.

This calls for a new administrative process which allows a man to be a member of a scientific section and yet work on a project with men drawn from other sections. This necessity usually leads to the designation of a Project Engineer, who is responsible for the general organization. Care must be taken to arrange the administration in a manner which gets the most good out of the laboratory without stifling initiative. The primary danger is that the scientist will find himself reporting to two superiors, the first being the leader of the scientific section, and the second being the Project Engineer.

While the project is still operating in the laboratory, it is desirable to order components for the system and the design of the smaller units from the scientific sections. In this way the best experience in science is made available. When the time comes for the assembly of the units into a complete system, then members of the scientific section must be recruited, and while working in this capacity, they must report to the Project Engineer. Needless to say, a tie to their own scientific section is desirable for two purposes: first, to insure that the best technical assistance is available, and second, to inform the scientific section of any new requirements or shortcomings of the units designed by that section. The division of responsibility is always somewhat confused as long as the system remains in the same laboratory as the scientific division. However, if the system is sent into the field for test or is removed from the main laboratory, the change in responsibility comes much more easily, since one can declare that when the system moves from the laboratory, all scientists then report to the Project Engineer. Obviously, these arrangements have to be tailored to fit local conditions.

Then if, by chance, the scientist reporting for one of these scientific sections goes astray because of lack of knowledge or inexperience, then the chief of that section has a chance to observe the results of the work and suggest improvements. Such a method gives access to the broader scientific knowledge encompassed by an entire scientific group and does not slow the progress of the report. This whole system can be best described by means of Table 2, where the various sections are shown with their major lines of administrative responsibility being crossed by the lines of project control under the various project engineers.

It is important that this type of organization be properly understood by the individual scientists; yet it must be impressed on them without calling their attention, in any irksome manner, to the fact that they are "under so-and-so." Organization charts posted in conspicuous places are in poor taste, and too often the employees start comparing their relative importances in the organization which, unfortunately, rarely coincide with the employees' own ideas of their importance.

The Progress of Research

A research laboratory, if it extends its field of operation to development and testing, will usually find its work going through a number of stages. The first requirement is a clear definition of the problem, a general description of the device it is hoped to produce, and some idea of how the goal is to be attained. The next step is to carry the projected plan into a more

scientific phase by making a thorough theoretical study and analysis of the proposed solution. Quite often such an analysis cannot be rigorous because of lack of fundamental information, which then must either be assumed or be found in a program of fundamental research. Which course is followed depends largely upon the urgency of the solution and its value in dollars and cents.

After these two steps have been passed, the next step calls for the construction of "breadboard models" of the various components, whether these are mechanical, electrical, acoustic, or optical. After the first breadboards, the development usually passes to a more refined stage with the components resembling, in some respects, the final model. The major differences will be the allowances which make possible changes in design and special arrangements to simplify tests. After successfully passing this stage, and proving that a workable model can be built, there is the design and construction of prototype models, these being as close to the final production designs as possible. After these prototypes have passed their tests successfully and all minor changes have been made as dictated by these tests, the final models, together with adequate drawings, are delivered to the factory. In this scheme, then, the products of the research and development laboratory are the prototype models, the prints and drawings, and the scientific reports which emerge from the research.

Disseminating Information

Every scientific employee must keep a notebook, if only for the legal protection of his employer. All circuits, data, and all ideas should be recorded immediately in such a book. Much of this information is of little use and is certainly of no importance except to the writer, but some of it becomes of vital importance. As the development of any research progresses, definite steps are completed, and a memorandum can be written to pass that information on to other members of the laboratory. This type of memorandum, which is limited to internal circulation, should not be limited in distribution. Certainly the scientist should address such a memorandum to all members of his particular group and all members of his section, as well as to any others who might have an interest or who might be capable of constructive criticism. This type of memorandum, however, must be clearly delineated from external reports and memoranda for publication.

Scientists have a very healthy curiosity about the work that their fellows are doing, and one laboratory finds it profitable to indulge that curiosity by publishing a weekly report containing brief accounts of the activities of all the scientists and technicians. These accounts, which are dictated on short notice, usually contain one hundred words or less and give the concept of what the author thinks he was doing or had accomplished during the past week. It is found desirable to edit such a report as little as possible and only to make sure that each account appears under the correct project heading or section number. Occasionally it is found that some scientist, by virtue of his own enthusiasm or by lack of proper administration, has wandered off into entirely new and irrelevant fields. The weekly report brings such an occurrence into violent focus and demands that the new work be approved or disapproved, depending on the evaluation of the management.

The Output of the Laboratory

All of the organization in the world will not make a laboratory an efficient one unless proper provisions are made for the collection and dissemination of the final product. This product can take a number of forms. It may be a set of designs and a model, which are sufficiently complete to permit the factory to set up production plans; it may be a set of tests which are concluded in a report; or it may be a paper which appears in the technical press. These should be considered not as the product of one man but as the product of the laboratory, a product on which the reputation of the laboratory will be built. Obviously, for the protection of the laboratory, everyone on the staff cannot be given the authority to transmit designs and models or to issue reports and publish papers. When a design or model is sent out, it should be sent out over the signature of one of the most competent members of the staff, who will take the special responsibility of making certain that everything stated in the covering report is factually correct and that the conclusions given are reasonable and represent the opinion of the laboratory. Therefore, the signing of such a report has to be reserved for the Director, the Assistant or Associate Directors, or at least to the group and section leaders. Obviously, in writing a report, some notice must be taken of the recipients, and very often only someone in the higher echelons of the laboratory is competent to judge the caliber and character of those for whom the report is intended and can thus design it to have a good chance of receiving a favorable reception.

For publication of papers in the technical press, a great deal more freedom can be permitted. Scientists consider it part of their reward to be allowed to publish such papers, and they realize that their own reputation, more than the reputation of the laboratory, rests on the success, veracity, and usefulness of those papers. Therefore, in this case the judgment of the management should be impressed much less formally.

The reputation of the laboratory and the individual members thereof depends largely on the product. Therefore, care should be taken to insure the product's presenting a good appearance. A very wise investment is the establishment of an editorial department, which can assist the scientists in saying what they want to say in language that is understandable to the expected audience. At times scientists resent editing of their reports, but if such editing is done carefully and judiciously, the scientists come to welcome such a system for what it is—help in making their reports as readable as possible. Sales departments insist on making the product look well and feature its best characteristics. This can also be done with reports. Photographs and illustrations should be carefully done. The typing should be as near perfect as possible and the language should be such that little further editing is required when the paper is sent to a magazine. When a paper is to be printed privately, the laboratory should make sure that no pains are spared in making the paper something of which the laboratory and the author can both be proud.

There is no guarantee that if all of the advice offered in this article is followed, a laboratory can be organized and become successful. In the final analysis a research laboratory, as any other plant, depends upon the personal touch of a director to grease the wheels

and help things run smoothly. No formula can be offered for this; it is something which is nurtured by careful work on the part of the administration and employees alike.

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Announcement of Visual Aids Exhibit at Annual Meeting

University of Texas, Austin, June 14–18, 1948

For the June meeting, plans have been made to exhibit devices that clarify engineering principles and phenomena that are otherwise difficult to explain. Many ingenious teachers in every branch of engineering have developed their own teaching aids which should be brought to the attention of other members of the profession. Professors Beatty of Pratt Institute, Conrad of Yale, and Secretary Bronwell are much interested in this exhibit which is being organized at their suggestion and with their counsel. The committee hopes that there will be a large number of these devices submitted, some from each field of engineering and its related sciences.

Unusual or original apparatus and models are particularly desired rather than more or less standard equipment which may be available commercially. It is felt that films and slides, in general, are in another category, and are not well adapted for this exhibit.

It is planned to have one or more custodians for the exhibit to watch over and demonstrate the equipment at times when the exhibitor may not be present. For the benefit of these men, a simple statement of operation and its significance should be furnished with each item. A card including the item exhibited, the name of the exhibitor, and a brief statement of the fundamental principle should accompany each exhibit. The Society cannot pay shipping costs or be responsible for damage to exhibits.

Members who have or know of such teaching aids that might be brought to the meeting are asked to write to the Chairman of the Visual Aids Exhibit Committee, so that the exhibit space may be provided, and any other necessary arrangements made.

PROFESSOR JACK LENHART,
Chairman.

VISUAL AIDS EXHIBIT COMMITTEE,
307 ENGINEERING BUILDING,
AUSTIN 12, TEXAS.

The United States Atomic Energy Commission*

By R. P. JOHNSON

Deputy Director, Division of Research, U. S. Atomic Energy Commission

Research in the Atomic Energy Commission

The term "Research," in the atomic energy enterprise, can without much stretching be applied to almost the entire business. The materials we deal with in carload lots, and the manufacturing processes that run their courses in our large plants, five years ago were unknown, or were known only on a laboratory scale. There are no old-time atomic craftsmen as there are old-time steel-makers and old-time pastry-cooks. Practically everything we do has to be done much as an experiment is done in a laboratory: with a degree of uncertainty about the outcome, an intention to learn from the experience, and an optimism that better methods can be found.

Even if the term "Research" is limited to those activities which cannot be called by some other name such as "Engineering" or "Production," still it covers an abnormally large fraction of the Commission's business—several times as large as in a normal business enterprise such as the Bell Telephone System or DuPont. The reason for this emphasis on research is, of course, that the possibilities of atomic energy are relatively unexploited, and appear promising enough so that a very sizeable effort to realize them is in order.

The research activity, whether the term is used in the narrow sense or with the broader meaning, is spread far and wide about the country. I propose that, for background, we take a brief look at some of the major installations, and have a word of description as to what goes on in each of them.

The center of the enterprise is here in Washington, down on Constitution Avenue. Here is the home of the five-man Commission appointed by the President, and the meeting-place of the statutory committees which advise and consult with the Commission. Here is a group of several hundred people—I am one among them—whose task is to aid the General Manager in planning, directing and reviewing the widely-assorted activities that make up the Commission's business.

Outside of Washington, there are five regional offices, set up on a semi-geographical, semi-functional basis, to administer such affairs as do not need to have centralized attention. Three of these offices are at or near the three isolated "artificial" communities that grew from nothingness in the war years—Oak Ridge, Tennessee, Hanford, Washington, and Los Alamos, New Mexico—while the other two, by contrast, are in the cities of New York and Chicago.

The Washington Headquarters, these five regional offices, and a few so-

*Address given before the Engineering College Research Council Meeting, Washington, D. C., November 12, 1947.

called Area Offices associated with particular installations, are the administrative machinery of the Commission. The work—the substantive work of production and engineering and research and all the rest—is done almost exclusively through the medium of contracts with industries and with universities.

One very important part of the substantive work is, of course, the production of fissionable materials from the source material, uranium. The major production plants are down at Oak Ridge and out at Hanford.

Let me just say, for the few of you who may have forgotten, that the Oak Ridge plant is an enormous, complicated sieve for sifting out the few uranium atoms that will split (U^{235}) from the many that won't (U^{238}). The Hanford plants produce plutonium, which has fissionable properties like uranium 235. Normal uranium, as a metal, is placed in some holes in a big block of graphite, and a controlled nuclear chain reaction (so-called) is set to going in this assembly. Some of the uranium 235 is used up by fission, and some of the uranium 238 is changed over, by nuclear processes, into the desired end-product, the man-made element plutonium.

This Hanford plutonium factory is strange in many ways. It is (to mention one peculiarity) probably the only manufacturing plant in the world where the fuel and the raw material are fed in all mixed up together, and the finished product comes out so intimately associated with the ashes that it takes a major effort of chemistry and chemical engineering to get them separated.

The two production plants, at Oak Ridge and at Hanford, are mammoth in size, in original cost, and in operating expenses. They are less efficient than one could wish. To build them and put them into successful operation in a few short years, with little to start from except laboratory experiments, calculations, and optimism, is rightly to be considered a marvelous achievement. However, it is also right to expect that the processes, all the way from the ore to the purified fissional materials, can be improved in greater or less degree, and that better production facilities can in the course of time be built. A part of the research effort goes toward the improvement of these production processes.

At Los Alamos, on a mesa north of Santa Fe, New Mexico, a variety of interesting research is in progress. The central task of this Laboratory and its associated installations is the development, production and testing of atomic weapons. The studies in this field are intrinsically very interesting; it is a deplorable thing that destruction is the ultimate end of this work, but in the world as it seems to be today the Commission has no choice but to go ahead vigorously with it. Weapon research continues; the Los Alamos Scientific Laboratory is its center; and I prefer to let this part of the program rest here without further discussion.

I want now to turn to another phase of the program on which I can speak at greater length, namely, the development of nuclear reactors for producing useful power. The major groups now working on this general problem are located at the Argonne National Laboratory in Chicago, at the Clinton National Laboratory in Oak Ridge, and at the Knolls Atomic Power Laboratory operated by General Electric Company near Schenectady, New York. Contributory work is done by many universities and industrial companies, too many for me to name here.

The nucleus of uranium 235 or of plutonium, when it splits, releases energy, just as an atom of carbon in coal, in combining with oxygen from the air, releases energy. A controlled nuclear chain reaction, such as the reaction that occurs in the plutonium factories at Hanford, yields energy in the form of heat, just as a coal fire under a boiler yields energy in the form of heat. We have long ago learned how to convert some of the heat of an ordinary fire into useful work. The technology of heat engines, after more than a century of development, is fairly well understood. Is it really much of a task, with all this pertinent experience behind us, to devise heat engines that will convert the energy released by splitting nuclei into useful work, and do this conversion efficiently enough to be of practical interest?

Let's see how much of the experience really is pertinent.

Take first the matter of size. If it is an air-cooled gasoline engine you want, you can pick your size out of a large range, from the little fellows that are used in model airplanes, all the way up to the giants, rated at thousands of horsepower, that turn the propellers on real aircraft. The fuel-air mixture burns just about as well in a little cylinder as in a big one. But with nuclear chain reactors it is a different story. Once the general *type* of reactor is chosen, the size is automatically fixed within fairly narrow limits. If there is not enough fissionable material present—if the reactor is smaller than a certain critical size—it simply does not work at all—there is no self-sustained nuclear chain reaction, no splitting of the nuclei, and no energy release. On the other hand, the reactor cannot be much bigger than this minimum size without involving serious difficulties in the matter of control. The designer finds himself rather tightly boxed in between these two limits. By planning to use enriched fuel materials instead of normal uranium he can get the minimum size of the reactor down to a manageable range, well below the size of the Hanford reactors, for example; but then if he wants much power output he has to design for high power production density, high temperatures, and high heat transfers.

This brings us to the question of materials. In ordinary heat engine technology, steel is the conventional structural material for fire-boxes, boilers, tubing, flues, etc. In nuclear reactors, ordinary steels just won't do. They absorb much too readily the flying neutrons that are the essential agents in the chain reaction. The same thing, unfortunately, is true of most of the other materials that come to mind as likely substitutes for the old standby, steel.

A very few substances, it now appears, are indifferent enough to free neutrons to be at all promising for structural uses. These materials are not familiar engineering materials. We have to learn, almost from scratch, how to reduce them from their ores, how to melt and cast and roll and forge and machine them. Their mechanical properties, their alloying properties, their corrosion properties, their heat-treating properties—all these have to be learned. In short, the engineering data, which in the case of steel have been accumulated in decades of large-scale engineering experience, have to be in large part accumulated for these other materials before their utility for nuclear reactors can be assessed with confidence. The handbooks for these ma-

terials are blank-books; it will take patient work to fill them with reliable numbers.

Purity is of prime importance, for any materials that are to go into a nuclear reactor. In the case of certain contaminants, chemical purity is not good enough.

What I have said about the structural materials applies also to the substances that are to be used for transferring the heat out of the nuclear reactor and into a heat engine of whatever kind is to be used. This fluid must have acceptable nuclear properties and must be pure of certain contaminants to a fantastic degree. It must, of course, also have the heat transfer properties that are required, and these requirements by themselves are exceptionally stringent because of the high heat flux that has to be contemplated.

All the materials that go into the reactor—structural materials, heat transfer substances, and nuclear fuel—have to be able to stand up under the bombardment of free neutrons. We know next to nothing about the effects of such bombardment on the physical properties of materials, but it is certain that these effects, for the neutron fluxes that will exist within a power reactor, will be far from negligible.

I think I have said enough about materials to suggest at least the fields of investigation which lie before us relatively unexplored, and which have to be thoroughly combed if substances suitable for use in a practical power-producing nuclear reactor are to be found. Our long experience with the technology of ordinary combustion and ordinary heat engines does not contain the answers that are needed.

In ordinary combustion, the fuel and the oxygen are almost completely consumed; the clinkers, the ashes or the waste gas can usually be disposed of fairly readily. The waste products of the nuclear chain reaction, contrastingly, are highly radioactive atoms which lodge right in the midst of the unconsumed fissionable fuel.

I should like to go into more detail about some of the technical problems I have mentioned, and add several more of equal difficulty to the list, but I think I have said enough to indicate the kind of work that goes on in the reactor development laboratories.

Every now and then I see a letter written to the Commission by some inventor who believes he can make a very simple machine for converting nuclear energy into useful work. In external appearance this invention sometimes has the form of a long tube with an opening at one end to admit the uranium and two terminals at the other end, from which electric power at 110 volts, 60 cycles, can be drawn in almost unlimited quantity. The internal giblets of this machine, we are assured by the inventor, will when they are disclosed amaze us by their simplicity. The device, we are informed, is notable for its lack of moving parts, for its ease and reliability of operation, and for its endurance through the years.

We wish it really were that simple. Today it seems not to be. To turn the energy of fission into the energy of a rotating flywheel seems today to be a long hard task.

I want to say a word now about the Commission's activities in the field of *basic* research, as contrasted with the applied research and development that are directed toward improved production, improved atomic weapons, and conversion of nuclear energy to useful work.

In the laboratories which work for us under contract by no means all of the research is strictly of the applied type. A very substantial fraction of the research effort goes into the study of problems which have no immediate bearing on the developmental task. In two of the large laboratories now supported chiefly by the Commission—the Radiation Laboratory of the University of California at Berkeley and the Brookhaven National Laboratory on Long Island—most of the research is of this non-programmatic type.

The Commission recognizes that, having by law a monopoly over certain tools and materials that are useful for basic scientific research, it has an obligation to make these tools and materials available to the scientific community with as much freedom as can be found consistent with the national security. Radioisotopes are an example; the Commission distributes these useful research materials to the public as an obligation, and expects incidentally that the research and training which are enabled by them will eventually contribute substantially to the success of the Commission's own development program.

Nuclear reactors themselves are another example. The large research reactor which is planned for construction at the Brookhaven Laboratory represents an effort by the Commission to make these new and important research tools available to the scientific community.

Our large programmatic laboratories contain many research facilities, including reactors, which can be used with profit for general scientific research and training. Universities and other institutions in the general neighborhood of the Clinton National Laboratory at Oak Ridge and the Argonne National Laboratory at Chicago have banded themselves together to exploit, for the benefit of their students and their staff, the peculiar opportunities for research and training which these two laboratories offer. The Commission welcomes this cooperation with independent educational and research institutions and is eager to see it grow in volume and in strength.

Aside from the many technical and scientific problems in which the Commission has a vital interest, there are a host of non-technical worries to plague us. Two groups of these I should like to mention briefly.

One is the whole complex of problems that goes under the collective name of "security." The fact that nuclear energy has been demonstrated as a great destructive agent, and the fact that the world today is a place where great destructive agents have more than an academic interest, force the business of atomic energy into unusual and unfavorable paths. They have made it necessary, in the first place, for the critical materials and the essential tools of atomic energy to be reserved as the exclusive property of a Government agency, instead of being open to the normal processes of development by free and competitive enterprise. Further, these two facts have made necessary a cloak of secrecy over certain fields of information, when all the experience shows that secrecy is not an atmosphere in which science and technology are apt to thrive.

A member of one of our advisory committees the other day summed up the matter in a single sentence. He said this: "If you want to do something and don't know how to do it, tell a lot of people you don't know how to do it." We find ourselves in the

position of wanting to do, quickly and effectively, many difficult things. We do not know how to do them, and we must be extremely careful to whom and in what degree we disclose the limits of our ignorance.

The most rapid progress toward our technical goals would certainly come through throwing our problems freely to the public and inviting anyone who can to help us solve them. The greatest secrecy, on the other hand, would be attained by keeping very close to ourselves the things that are now known, and foregoing all hope of adding rapidly to our store of information and skills. Somewhere between these two extremes lies the course which will best assure the common defense and security in the world as it is today. We have to pick our way step by step along a path of compromise, recognizing with every step that progress toward the technical goals is slower—has to be slower—than it could be in a world free from the threat of war.

The second problem concerns people, people to do the research and development and engineering that have to be done in the immediate future, and people in even greater number to take their places in the expanding field of atomic energy foreseeable for the coming years. This problem of people is unfortunately not easily to be separated from the problem of security which I have just mentioned. For example, if all the available information were public knowledge it would be the business of you gentlemen here and your counterparts in other colleges to assess as best you can the future of the business, to adapt your courses of study to include this new field in its correct proportion as you judge it, and to call the attention of your students to the fact that nuclear engineering will probably be offering thus and such opportunities for interesting employment. The matter, in short, would be largely self-adjusting.

I think it is safe to say that atomic energy is here to stay, that nuclear science and the technology which can be built around it will grow and will become increasingly important in the next few decades. Students who elect to learn the fundamentals of nuclear science are likely to find that this information will be valuable to them in their later employment. Institutions which set about to emphasize these subjects in their courses of instruction are likely to find that they have been foresighted in so doing. Research people who turn their talents to this field can look forward with some assurance to the satisfaction of having contributed to the building of a substantial enterprise.

The Atomic Energy Commission, with so many tasks which it alone *must* do, is not disposed to take to itself any work which can properly be assumed by someone else. It is certainly our duty, whenever such an occasion as this presents itself, to state our view that the coming importance of atomic energy matters is rather greater than can be inferred from the bits of information which are published. We then have to invite you and your colleagues to take this estimate seriously into account in your planning.

Replacement of Equipment from the Viewpoint of a Teacher of Engineering Economy*

By FOREST C. DANA

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Introduction

The financial aspects of the problems of replacement are now and, for some time to come, will continue to be a question of high importance. Not only large concerns but the smaller plants and individuals as well have a vital interest in these problems. There are several reasons for concern in the methods of handling these problems. First, of course, finding equipment at all has been a vexing quest; second, the rocketing prices have made economy studies imperative; third, the high cost of labor is forcing employers to the use of more and better machinery.

Teachers must remember that our students are merely a small cross-section of the total population with the same attitudes and buying habits as the common citizen. It is unfortunate but quite generally true that our engineering teachers seldom refer to the financial side of their design problems. Their foremost concern is with the theory of design and they have little interest in adapting designs to available funds. Thus it is a shock to our graduates to discover that fine, accurate, theoretically ideal designs are not enough. They are unhappy when they discover that cost, expediency and various intangible factors often outweigh all other considerations. Thus many a beautiful design must be rejected simply because it costs too much.

Basic Facts Are Vital

Where, then, should the teacher of engineering economy start and how far should he go in treating the details of the subject of replacement economy? His foundation should be laid in his presentation of four basic facts that must be recognized by any worker in this field. Failure to recognize one or more of these truths leads to fuzzy thinking, wrong answers, and unjustifiable conclusions. Those basic facts are as follows:

1. All costs must be carried eventually by some individual or group of individuals.
2. There are no theoretical formulas that will lead to exact and invariable answers.
3. There is no substitute for good judgment and wise reasoning.
4. There is no general agreement as to the "right" and "wrong" method of handling many items.

1. Costs must be carried by some one. This is not the time for a discussion of the movement of wealth through its

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various channels of business but it should be obvious, however, that for any given firm, equipment can be paid for in relatively few ways. They are as below:

a. By the ultimate consumer of products or services as a part of the price he pays.
b. By the stockholder as a reduction in the share of dividends he normally receives.
c. By employees in the form of lower wages and salaries or elimination of raises.
d. By creditors if the business fails.

The primary fact is that, in all cases, the costs ultimately are distributed to individuals. Students must be brought to the realization that there is no financial Santa Claus to save one from economic blunders. In spite of the beliefs held by various groups in this country for many years, the United States Treasury is not a financial blood bank that replenishes itself and can be drawn upon at any time without restraint. We may refer to various reserves and accounts by technical words but there is no magic in a name—like the blood banks in hospitals they must be built up, little by little, from small contributions by individuals. The various costs may be divided unevenly and individuals will try to shift them until ultimately they fall on men who cannot escape them. The resulting ebb and flow of our economic tides merely represents the effect of these efforts to shift the financial burdens to other shoulders.

2. The second fact which is a stumbling block to many students is that it is impractical, if not impossible, to devise mathematical formulas that can be used mechanically in economy studies. There are too many variables, too many long range forecasts, too many "guesstimates" of future values, and too many intangibles that defy measurement. While it is true that many formulas are used and that any calculations must be accurate, the results obtained by them are only part of the answer. The student must learn to recognize the limitations of the formulas he uses.

3. The necessity for the constant exercise of judgment is the third foundation fact. Formulas break down when the variables cannot be measured precisely and estimates only can be used in the calculations. Foresight is dependent upon experience, not upon some mystic pre-vision. Frequently there are intangibles that must be evaluated and only experience can serve as a guide. Thus in the end the reliability of the decision rests upon the wisdom and judgment of the estimator.

4. The fourth fact to be accepted and lived with peaceably is that frequently there are no generally recognized "right" or "wrong" methods of solving certain problems. Even among engineers of recognized standing there are wide differences of opinion as to the merits of various formulas. Some will no doubt take exception to the statement but, in truth, there is no RIGHT depreciation method; no RIGHT interest rate. The RIGHT value for the useful life of a machine cannot possibly be known until the machine is retired. By that time it is too late for the information to be of any value in setting up a depreciation schedule for the cost accounts. A glance at the rise and fall of interest rates in the past should make one chary of being overly positive as to the future rates.

The above basic facts are the ones the student must learn to accept without a feeling of outrage at discovering he has entered a field where good judgment

and arbitrary decisions, not mathematics, have the final word. With this foundation laid students are ready to study the problems of replacement.

The Problems of Replacement of Equipment

The writer has tried various approaches and has found that the analysis which should be presented first is that of the total annual cost comparison. Students grasp this idea with the least trouble. Increment costs, unit costs and capitalized costs should be treated as alternative views of the problem, not as independent methods.

For replacement problems students should be trained to analyze each situation individually and completely without blending items. Many men tend to set item against item but this procedure never gives the complete, rounded picture. Students will get better results when they begin the study of replacement problems if the conventional accounts groupings of items is more or less ignored. They should break their analyses into a few broad groups of items. The writer has found students manage the problems more successfully if each one has its data broken down into these groupings:

1. Items related to the capital invested in the machine.
2. Items related to the operation of the machine.
3. Items related to the necessary manpower.
4. Items related to the product.
5. Items related to management.
6. Items not fitting above groups.

Each of these groups can be broken down into numerous main items and sub-heads. Students should, if possible, be led to see that each group is a consistent whole and costs belonging in the group should be placed where they belong and not be thrown together in the problem helter-skelter.

1. Items related to capital invested in machines.

In replacement problems the in-place values of both machines, the existing old and the proposed new, ready for operation, are the values to be estimated. The values should be as of the date of the proposed replacement. The in-place value is defined as the sum of all costs, known or estimated, that are directly chargeable to the machine in order to get it ready to produce. If it is a new machine, it is the cost new, F.O.B. the dealer's dock, plus transportation to its building, plus all installation costs. For the old machine the in-place value is the going market price of a used machine of like type and condition if purchased from a second hand dealer, plus the transportation from his floor, plus the fair installation costs as of that date.

The book value of a used machine should have no significance in the replacement problem. Any difference between the in-place value and the "book value" represents an over or under statement of life in estimating the depreciation rate at the time the accountant's depreciation schedule was set up. These differences should be charged off in the surplus account and if there is an apparent loss it should certainly not be charged to the new machine.

When the in-place value has been estimated the possible salvage value must be considered. This must be a guess as to future markets and the date for this value must be based upon another guess, that of the probable useful life of the new machine or the expect-

ancy of the old, existing machine. This life figure cannot be set accurately unless management adopts a fixed policy of replacing equipment at the end of a certain term regardless of condition or usefulness. The teacher should emphasize that although exhaustive studies have been made regarding the probable life of equipment, all of them are historical studies and not one of them really applies to a new model. In the last analysis, therefore, an estimated life must be based upon the record of older machines of as near as possible similar type in similar kind of service. This will be an arbitrary value which the estimator must adjust if he believes the local conditions differ from the average. Since the salvage value is only an estimate, one should be very conservative, not to say pessimistic, about the matter. Some estimaters prefer to forget about second-hand values and use mere junk values. This substitutes one guess for another without much gain of precision. There are cases where it costs more to remove the equipment than it is worth: the end-of-life value may be negative.

The choice of the formula or method to be used in computing the annual depreciation charge is a most puzzling affair to most students. Their trouble is the same as that of many engineers—they do not see the underlying reason for the charge. Older engineers who have followed the heated arguments regarding the merits of straight-line, sinking-fund, present-worth, or other methods have noted the confusion as to the basic significance of the charge.

Its purpose can be stated in few words. *It is for the recovery of the capital invested in the machine.* If the machine is paid for in full at the time of installation this prepaid expense should be recovered in some orderly manner so the machine will not be sold piecemeal to the customers. The money thus recaptured may be reinvested in part or in whole in another machine or be put elsewhere in the plant. In practice the annual charges for depreciation are usually re-invested in plant expansion or used elsewhere in the business as the money is recovered. The annual depreciation charge is NOT made for the purpose of paying for a new machine some time in the future nor is it to pay for a machine long since retired. It has one purpose only; namely, to recapture the capital invested in *that* machine. Management can, of course, waste the capital thus returned but at least it is not dissipated by unduly low charges to the customer.

It follows, therefore, that there is probably no single RIGHT depreciation method to be used at all times. The method that should be adopted is the one that fits the needs of the concern reasonably well, is not unduly costly to apply, and attempts no refinements of precision that are more than offset by the probable errors in the basic assumptions. When there is little choice between methods, then it is the function of management to make an arbitrary decision in the matter.

While profit, sometimes called interest on the investment, is not allowed as a cost for income tax purposes it is none-the-less an item that must be considered in replacement problems. Logically it should follow the depreciation calculation since the interest rate is related to the depreciation calculation. The choice of the interest rate is again a matter to be settled by an arbitrary decision based upon judgment and experience. It should be chosen on the basis of present circumstances as well as the history of the enterprise.

2. Items related to the operation of the machine.

In this are included such items required to keep the machine producing. Thus such costs as the following are entered in this group: maintenance, repairs, inspection, supplies, power, space charges, anything that can be charged to a given machine.

3. Items related to the necessary manpower.

The common classifications of direct and indirect labor not only apply but, for replacement problems, other costs that are really tied to labor cost and fluctuate directly with it. Some of these costs which ought to be included in the problem are: workmen's compensation, social security taxes, unemployment taxes, pension costs, union welfare funds and similar items. There are also times when minor supervision should be included here.

4. Items related to the product.

The ordinary classification of direct and indirect material applies. The item of unavoidable waste material must not be neglected.

5. Items related to management.

The writer dislikes the word "burden" when discussing these costs as the word has a definitely unfavorable or negative connotation for the student, leaving him with the idea that they should and can be eliminated. If they are described as the aggregate of the costs which cannot possibly be segregated and allocated to individual machines, the student has a more open mind. These costs include such items as office supplies and equipment, typists, bookkeepers, printing, building expenses and depreciation, salaries of officers from foreman to president of the company, and many other items small and large.

6. Items not fitting into above groups.

Even with the best of accounting and bookkeeping systems there will always be a collection of items that seem to be hard to classify but that should be considered in a relative economy problem. Two such items are insurance on the machine and its share of the property taxes.

If students can be induced to make check lists of these main groups and the items in them, then make their calculations follow the same order, they will make fewer blunders. Too little emphasis is placed by many teachers upon logical, orderly calculation procedures so that many students tackle a problem much as one tries to start a balky alarm clock, they rattle it around hoping something will fall into place and the problem will solve itself.

Special Cases

In the preceding topics the basic elements and approach have been discussed. With the fundamental principles clearly fixed in their minds students are ready to consider the numerous variations that occur. Each of these will be found to be a special case in regard to certain items to be considered. For example, consider the situation where a machine is to be replaced before its anticipated useful life has been reached. It matters little whether it is obsolete or merely inadequate. If its book value is greater than its salvage value, charge the difference to surplus for that is where the sum has really gone. If the book value is less than the salvage value credit the surplus with the difference for the capital was recovered at too high a rate.

Whenever the present old machine is still serviceable, but replacement is considered, the old machine should be given the benefit of the doubt. Its in-place value should be used and the annual cost of its remaining service life should be the basis for the cost comparison. Any major repairs or rebuilding costs should be added to the salvage value as a part of the in-place value. The proposed machine, on the contrary, should be on the defensive. All estimates as to its life, operation and other costs should be conservative, if not gloomy. Too much equipment is bought merely because it is new and pretty and the salesman is persuasive. Thus the estimator should not expect too much in the way of long life, future salvage value, or freedom from repairs. If the old machine is being retired at two-thirds life, then the proposed machine will probably do no better if as well. In a word, put the burden of proof on the new machine.

Sometimes, however, management goes too far by saying that the new machine must "pay for itself" in a very brief time, say one to five years. If the depreciation account is really set up this way, then the effect is to increase profits as soon as the investment is written off. The Federal Government will then levy full income tax since no more depreciation can be charged. If the depreciation schedule is really set up on a normal basis while the purchase was based upon an accelerated write-off then the profits are of course increased over the entire depreciation period and the machine may repay its cost many times over. The customers are thus forced to pay an excessive profit over what should have been paid had normal figures been used. Such a technique works fine for companies in a monopolistic position but in competitive fields there are dangers from this practice; business can shift to a less avaricious competitor.

When time permits, students should receive information about the various ways of handling the depreciation account and reserve. The first fact to be made clear is that seldom is there any actual fund or reserve of cash or other liquid assets earmarked for replacement purposes. The name "Reserve" is a misleading fiction. It identifies an appearance with reality; in many cases it is a form of self delusion and the term could well be abandoned. In actual fact replacements are paid for out of working cash or by borrowed funds. Thus the amounts deducted from profits under the name depreciation charge are merely sums free from income tax and, in fact, the monies are mingled with other corporate funds and lose all identity. Thus while there is such a thing as actual physical depreciation due to wear and tear, the term as used in replacement studies usually refers to an arbitrary value set for the convenience of the accountant. He knows little and cares less about the actual physical condition of the machines from year to year. If he has been able to write off the capital investment by the time the machines must be discarded he is satisfied. Since the purpose of the depreciation charge, therefore, is the recovery of the funds invested in the machines and not the acquisition of the purchase price of any new machine, it does not matter at all that the recaptured money has been reinvested elsewhere in the business.

In the few cases where an actual funded depreciation reserve exists the money is there, distinct from other funds, labeled and available for replacing equipment. Such funds do not need to be completely liquid but can be

in securities that have maturity dates the same or somewhat shorter than that of the equipment in service. Safety is paramount, liquidity important, hence interest rates are low. For this reason management often prefers to put the funds back into the business where higher returns are probable.

The true reserve has certain advantages, however, especially when money is hard to get. No new capital is needed, no inroads need to be made on the working capital and there is no need to borrow from banks or other lenders. Thus a firm that follows this policy is in a highly enviable position when the money market is tight. The loss of interest on the fund, because it earns at a low rate, can prove to be a cheap price to pay for independence.

In conclusion, the writer confesses that he tends to be conservative, to play safe on investment problems. No one goes broke who carefully considers his expenditures, who requires a dollar's worth of service for the dollar expended, who faces facts, who takes a profit great or small and leaves the chance-taking to the other man. The old Chinese proverb, "When prosperity comes your way do not spend all of it," is still valid.

Necrology

Dr. William Lindsay Malcolm, 63, director of the School of Civil Engineering at Cornell University since 1938, died January 18 at Tompkins County Memorial Hospital following a heart attack. A native of Mitchell, Ont., Dr. Malcolm came to Cornell from Queens University, Kingston, Ont., where he had served from 1907 as assistant professor of civil engineering and professor of municipal engineering. During 1914–19 he served overseas with the Canadian Army Engineers, attaining the rank of lieutenant colonel and commanding engineers with the 4th and 5th Canadian Divisions.

Dr. Malcolm, an authority on sanitary engineering, had served as city engineer of Stratford, Ont., associate city engineer of Guelph, Ont., and as a consultant on Canadian highway and building programs.

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George F. Bateman, Dean of the Cooper Union School of Engineering, died of heart illness Thursday evening, January 29. Dean Bateman has been on the faculty of The Cooper Union since 1907 and was Dean of the School of Engineering since 1933. He was president of the New York Electrical Society for two terms, from 1944 to 1946, and a Director of the Society since 1940. He was a member of the Publications Committee of the American Society of Mechanical Engineers, and Chairman of its Publication Committee in 1939. He was active in the A.S.E.E. and a member of its Council and Chairman of its Committee on Meetings for the Middle Atlantic Section.

Engineering for Profit*

By E. B. MATHEWSON

Executive Vice President, North Star Woolen Mill Company, Minneapolis, Minn.

This talk, "Engineering for Profit," is a case history of a program which we at North Star have been working on for the past four years. This case history describes what we did in our manufacturing plants at Lima, Ohio, and Minneapolis, Minnesota, to bring about

First: increased productivity per man hour,
Second: increased earnings per man hour,
Third: improved labor relations,
Fourth: improved management organization, and
Last: development of the company's philosophy of management and broad aspects of its postwar program.

All we did was to apply scientific and engineering methods—and I would like to show you results from its practical application in woolen mills. Your interest in the results of this program may be from an engineering angle; it may be from the standpoint of labor relations; or it may be from from the viewpoint of management organization —all of which is part of the development that took place in these two plants.

As you may know, we are manufacturers of all wool blankets, and operate three woolen mills—one at Lima, Ohio, one at Wakefield, Rhode Island, and the other here in Minneapolis. In order for you to understand the problems with which we were faced in 1943, I would like to give you some of the background of what I found in Lima, Ohio, in the spring of 1943, which was my first association with the company.

At that time the North Star Woolen Mill Company had owned and operated the Lima plant for approximately two years. The plant had low wages, low man hour productivity, incompetent local management, poor labor relations and a profit picture far from satisfactory. This is rather a severe but true criticism of conditions. The change in thinking which took place at Lima was forced upon the local management by the Union and its local and national officers. The Union in this particular plant is the Textile Workers Union of America (C.I.O.). They were activated by the fact that while their wage scale was low, under the Little Steel Formula they could not get relief in base rates, hence, they forced management to take steps to install sound wage incentive plans in order to allow employees to increase their earning power through increased productivity.

In order that we may measure the improvement which took place in our Lima plant between June of 1943 and June of 1945, here are some statistics

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based on the operating results for the last week of June, 1943. These figures will later be compared with figures for the last week in June, 1945.

Total direct and indirect employees on mill payroll	257
Total units produced	6,933
Total man hours	10,602
Total mill payroll	$7,520
Average take home pay per hour	70.9¢
Units per man hour	.65
Mill payroll cost per unit	$1.084

I will come back to the above figures later when comparing these results with the last week in June of 1945.

So here we have the setup. A plant ready to blow up from poor labor relations, high cost and low employee earning power, and a local management incapable of taking corrective steps. The management of North Star brought me into the picture, as a consulting engineer, to see what could be done to correct the operating conditions of this plant, putting it on a more profitable basis, increasing the earning power of the operatives and developing a sound labor policy.

Our first approach was directly to the Union, with whom we worked out a step by step program to install, through the route of sound methods engineering and time study, wage incentive plans in such departments in the mill as could be placed on an incentive basis of payment. No particular type of wage incentive plan was decided upon, as each department would have to be studied by itself, and use whichever method we finally determined to be the most practical to measure and pay for increased productivity. At all times we had to keep in mind the fact that if the wage incentive plan was complicated and not easily understood by the operatives, the possibility of acceptance by the Union and employees would be remote. Furthermore, as the workers were suspicious of the local management we had to be very careful and go over each departmental plan in complete detail. The following guiding principles were finally agreed upon.

1. Each wage incentive plan would be based on complete and detailed time studies.

2. No work load would exceed an average of 85 per cent.

3. Present day rates would be established as minimum guaranteed rates per hour.

4. Incentive earnings would range from 15 per cent to 30 per cent above the guaranteed minimum rate per hour.

5. Where possible, incentive earnings would be calculated on a daily basis.

6. All incentive plans to be installed for a four week trial period before final acceptance by the Union.

7. All incentive plans to be approved by the War Labor Board.

With these guiding principles agreed upon, we proceeded, department by department, to study operating methods and determine—

First: Based on sound time study and methods analysis what improvements we could make in operating methods within the department.

Second: Once we had established the proper operating routine, what type of incentive plan should be used as a basis of production measurement and wage payment.

Third: Present each plan as a recommendation to the Union and to the Company management.

The results of these department programs were that in some cases we used

straight piece rate methods—in others we used group or pool incentive plans. For example, in the spinning department we put draw counters on the spinning mules, and put the spinners on a straight piece rate basis, paying a rate per hundred draws. In this way the operatives could check their production daily, and knowing the rate per 100 draws could calculate their pay at any time they wished. This made a very simple method of calculation and a very accurate method of production measurement. This, of course, was the most simple form of wage incentive payment which we installed. In the finishing department, for example, where we had a sizable group of workers doing various jobs, all of which applied to the finishing of a piece of cloth, we established a pool rate based on standard man hours, whereby we guaranteed the dollar rate per unit, and let the employees split the pool each day, based on relative man hours. This type of incentive payment was very effective, particularly with the shortage of help, as days when people were absent the balance of the group could earn substantially more money per hour if they maintained a high level of productivity, due to the fact that they split this dollar pool.

Step by step we studied each department, corrected its operating methods, determining the method of incentive wage payment, selling the idea to both management and labor, putting the plans into effect following approval of the War Labor Board, watching them very closely during their four week trial period, and as the wage incentive plans proved themselves to be effective from a production and earning standpoint, turn them over to the local management to maintain and move on to the next department. In some cases we discovered that new equipment was necessary. As an example, forty automatic looms were installed, taking the place of forty-eight manual looms, with a substantial increase in production and decrease in number of operatives. (Automatic looms are operated four to a weaver; manual looms are operated two to a weaver.)

This entire program took about a year to complete, and the results were, in our belief, rather staggering. As a comparison with the figures quoted earlier in this talk, let us see what the figures look like as of the last week in June, 1945.

Total direct and indirect employees on mill payroll	128—decrease of 50.2%
Total units produced	8,059—increase of 16.2%
Total man hours worked	5,508—decrease of 48.0%
Total mill payroll	$5,106—decrease of 32.1%
Average take home pay per hour	92.7¢—increase of 30.7%
(This is an increase of 115% from June of 1941 when the average take home pay per hour was 43.2¢.)	
Units per man hour	1.46
Mill payroll cost per unit	63.3¢—decrease of 41.7%

Here we find a program which is paying off in the employees pay envelope and in the company's Profit and Loss Statement.

During this entire program constant improvement was noted in the attitude of labor towards management. Suspicion and distrust were reduced to a very minimum, grievances were acted upon rapidly, and with an honest attempt by management to solve them to the mutual satisfaction of the em-

ployee and the Company; contract negotiations were entered into with good will by both labor and management—the resulting contracts being both practical and workable.

As the results of this program were beginning to shape up, the North Star organization realized that a similar approach to some of their problems might prove advantageous and assist in the elimination of certain bottlenecks which had developed within the plant, as well as assist in improving labor relations. Hence, early in 1944 we started to tackle bottleneck departments at the North Star plant, applying the same principles of methods engineering and time study which were developed at Lima. Our path was somewhat easier, as the results of the Lima program had become known to the labor union at North Star, and they were anxious to benefit by the application of these methods. Every department in the plant has been studied, and from these studies we determined the best method of operation, the proper complement of personnel, a method of production measurement and a method of incentive compensation, following the same principles which were used at Lima, whereby we expected these wage incentive plans to result in increased earnings from 15 per cent to 30 per cent per man hour. In some cases, however, earnings have exceeded this limit. The results at North Star paralleled those at Lima. Improved labor relations followed these method studies, due largely to labor discovering that they could trust management, and that management was doing everything within its power to assist in improving the employees' working conditions and increasing their earning capacity by compensating them for their increased productivity.

As an example of the results of some of the engineering work performed at North Star, we made an analysis of man hour and payroll cost per unit of production for the week ending May 18, 1947, and compared it with similar figures for the week ending May 19, 1946. This was just a spotcheck and showed the following results:

During this year period the employees' earnings per hour increased 18.2 per cent. The man hours per unit of production decreased 12.8 per cent. The labor cost per unit increased 3.3 per cent. A negotiated wage increase was made effective April 7, 1947, equalling 15.2 per cent. Therefore, these figures show that we have been able, through the route of increased productivity per man hour, to nearly absorb the wage increase with only a slight increase in labor cost per unit.

An example of some of the types of wage incentive plans we have installed in our Minneapolis plant is the one in the Maintenance Department. The need for this was brought about because of the fact that our highly skilled millwrights, master electricians, etc., were earning, on a day rate basis, less money than certain of our highly efficient wage incentive departments where the increased earnings of the department were due to increased productivity. This created a condition in our plant which meant one of two things—either increased hourly rates for our Maintenance Department, or some sort of incentive program whereby they could participate in increased earnings due to increased productivity. A plan was made effective measuring the relation of hours of maintenance to the hours of plant activity, and has resulted in a bonus earning for our Maintenance Department of about 23 per cent, and a de-

crease in maintenance cost to the company of somewhat over $250 per week. At the present time every department in the Minneapolis plant, with the exception of the general plant labor, janitors and boiler plant operators, is paid under some form of incentive plan.

After management and labor realized they had a common stake in this program we mutually agreed that in order that proper base rates could be established in these mills a job valuation study should be made, and as a result, every job in each plant is now being paid on an evaluated rate structure. This applies to day rates only—not incentive earnings. Incidentally, we have recently extended our job valuation program to include all salary personnel below the ranks of company executives.

As this program progressed we noted a marked tendency toward improved management organization and management techniques. We were forced to become better executives. We were forced to do a better job of production planning; of maintenance; of purchasing. We came to realize that efficient management was not only the efficient use of management tools, but also a state of mind. And gradually we noted a philosophy of management developing, which we have now put into written policy and have made known to all the employees of the company. This philosophy of management was described in the following talk which was given before the employees of the company at their annual party on July 29, 1945.

"Before we describe what North Star's labor and management program is today, and as we visualize it for the postwar era, let us examine our philosophy of management. Up to now it has been a vague thinking—something which we have mentioned and talked of but have never completely identified as a written policy. Hence, here is North Star's philosophy of management:

"To manufacture a product of the highest quality possible, at the lowest unit cost possible consistent with this high quality, and pay the highest wages possible—all this to be complemented by a capable management, a broad and constructive merchandising and distributing policy, continuing product and process research—all this built upon a sound labor management relationship.

"With this management philosophy in mind, it is our opinion that you should know what your company is doing: First, to prepare for what we believe will be the most highly competitive era in American industrial history, and, second, to insure the perpetuating of this management philosophy. The combination of these two should result in a continuity of employment at a respectable wage level.

"In talking about what North Star is doing:

1. We believe our first responsibility is to put our physical properties in the most efficient condition possible. In order to do this we have either purchased, or are purchasing, nearly three quarters of a million dollars worth of machinery, equipment and plant construction. It is only because your management has confidence in you and in its philosophy of management that it is willing to make this investment.
2. In order that we may use this machinery and equipment to achieve the highest quality possible, we are developing a research organization—an organization which through the years will assist us in applying the most advanced as well as practical methods possible in order to improve and to control our quality at its highest possible level.

3. The development of a technique of planning and scheduling which will insure the delivery of merchandise to our customers in the quantity they require when they require it, and to insure a proper flow of production within our manufacturing units.
4. The continued development of manufacturing technique, and the assistance of properly constructed wage incentive plans, thus insuring a high man-hour productivity.
5. The establishment of a sound job valuation program, supplemented by a sound minimum rate of pay as negotiated through the medium of collective bargaining, thus insuring a good basic wage level for our employees. By tying in this basic wage level with our wage incentive plans we also will properly compensate our employees for their high productivity. All of this is what we mean when we say in our philosophy of management, 'To manufacture a product of the highest quality possible, at the lowest unit cost possible consistent with this high quality, and pay the highest wages possible.' The assumption is, of course, that at all times you will be supplied with as fine a quality of wool as we determine necessary for each type of product.
6. In the field of distribution and merchandising, we are developing one of the finest field organizations, not only in the textile industry, but in any industry. At the present moment we have twelve high grade, well trained and experienced sales representatives, headed by an assistant sales manager in charge of these branch and field operations. This is being constantly expanded as we determine from market research what new territorial coverages are necessary. We are establishing a contract division, which will sell hospitals, institutions, hotels, airlines, railroads, etc. We have established a very efficient home office sales organization under a capable assistant sales manager in order properly to handle and expedite customers' orders and shipments, assist in the planning and scheduling of production, and handle the merchandising and promotional phases of our business in conjunction with our merchandising consultants.
7. We are in the process of starting the development of a specialized fabric program—a program which we hope will eventually give us a volume of high grade fabric yardage, which we believe is necessary, in conjunction with our blanket program, to insure a continuity of three shift operation in these plants. This program will be headed up by a capable cloth fabricator, and one who will be entirely responsible to the management of your company for the complete development of this cloth program. This is just further indication that North Star is cognizant of the volume needs of these mills if we are ever to maintain full three shift operation.
8. We are developing a technique for market research, which department is now headed by a specialist in this field, in order to determine where we should sell, whom we should sell, what we should sell and how much we should sell.
9. Our sales organization is being assisted by one of the most outstanding merchandising and promotional programs in the history of the woolen textile business. Our advertising counsel, in our opinion, is tops in this particular field. They in return have taken an extreme interest in the development of your company. They have assisted in the development of its management, they have assisted in the development of its policies, and they are interpreting all of this into a merchandising program with which to create a consumer demand for our products.

They are establishing this program on a national scale through the medium of advertisements in national publications, a clerk educational program, research in the field of blanket department layouts and various other things which will assist a store merchandising manager not only to do a better job for his store, but at the same time to sell more North Star products.

10. We have developed what we believe is a capable management organization. This organizational structure was included in the May issue of the *Comet and Planet* in order that you might see exactly what type of management North Star has developed. We sincerely believe that man for man there is no company with a more capable or qualified top management. Furthermore, we believe that this top management is well organized and directed. We have a staff committee, consisting of the President of the company, the Vice Presidents, the Assistant Secretary and Plant Manager for the Minneapolis plant, the Vice President and Manager of the Lima plant, and the Treasurer and Comptroller of the corporation. This Committee meets once a month for a period of from two days to a solid week for the purpose of determining the policies of the company, and recommending such policy changes as may be necessary to the Board of Directors. Furthermore, this staff committee is responsible for the carrying out of such policy and for the sound and proper operations of their respective organizational responsibilities. This is what we mean when we state in our philosophy of management, 'All this to be complemented by a capable management, a broad and constructive merchandising and distributing policy, continuing product and process research.'

"All of this will not survive, and perform its functions in the manner in which it should, unless it is built upon a sound foundation. In our opinion, this foundation is a sound and intelligent labor management relationship—a relationship which is practical and realistic; a relationship in which labor and management have confidence in one another; a relationship in which labor and management trust one another; a relationship in which all suspicion of each other has been eliminated. We recognize that such a relationship may be Utopian; however, we must all do our part in attempting to bring about such a condition, as it is only on a basis of this type that the tremendous program outlined here can be carried out successfully. We respect the rights of labor to organize; we respect the rights of labor in the field of collective bargaining—the management of North Star shall always bargain with labor with good will. We understand the three motivating principles of Unionism—its right to good working conditions, its right to security (*i.e.*, continuity of full employment at good wages), its right to status or to the respect of management. In return for all of this, labor shall have to assume its responsibilities in assisting management, within labor's scope, in carrying out this philosophy and attempting to attain this goal. It is only by the cooperative effort of labor and management that our common goal shall be reached."

We have coordinated the effectiveness of men, machines, material and money, and it is our opinion this must be the goal of every successful enterprise.

We have attempted to give you an outline of what we have done in our plants to promote better labor relations, better organization, more efficient methods of management in order to be prepared for this competitive era.

The Transfer of Students from Emergency Institutions in New York State*

By N. S. HIBSHMAN

Dean, School of Engineering, Pratt Institute, and President, Association of Engineering Colleges of New York State

Last June in Minneapolis, Dean Hammond reported the results of a survey of enrollment in emergency colleges throughout the country. It appeared then that the numbers of engineering students "farmed out" or otherwise engaged in "pre-engineering" study outside the established colleges was so great as to preclude any possibility of absorbing them into the regular classes in the near future. As an appendix or footnote to that report it may be of interest to review briefly the problem and the effort towards its solution in one state.

In some ways the situation in New York State is typical and in others it is unique. The state's fifteen engineering colleges represent about ten per cent of the national facilities and enroll about ten per cent of the United States engineering students. Practically all of the curricula recognized by ECPD are offered within the state. All types of institutions are included. There are small specialized schools devoted to one curriculum. There are large technological institutes with a variety of graduate and undergraduate curricula. Another group share their campuses with liberal arts colleges. Two are parts of purely professional schools. Several are parts of large universities. Graduate and undergraduate curricula are available to evening students in some of the institutions in the state.

Half of the engineering colleges of New York State are in the metropolitan area and half are located in smaller communities throughout the state. One operates on municipal funds and another is partially supported by the state. The rest are privately endowed and controlled.

All of these engineering colleges and the institutions with which they are associated are, by virtue of their accreditation by the State Department of Education, included in The University of the State of New York. This voluntary federation of the educational institutions of the state is unusual if not unique. There is no state university. State scholarships may be used at any of the private, independent colleges accredited by and therefore part of the University of the State of New York.

The colleges and universities of the state are otherwise organized according to their own interests and desires. The fifteen engineering colleges formed a few years ago The Association of Engineering Colleges of New York

* Presented at the Engineering College Administrative Council Meeting, Washington, D. C., November 12, 1947.

State. This is a conference of the principal administrative officers of the engineering colleges for the exchange of information and joint action on mutual problems.

When the deluge of applications for college admission came in the spring of 1946, the governor appealed to the colleges to expand their facilities and set up extension centers to accommodate the veteran applicants. Several of the engineering colleges of the state assisted small liberal arts colleges to set up pre-engineering curricula with the expectation that students who completed one or two years in these institutions might eventually transfer to the engineering colleges whose facilities were expected by that time to be ready to receive them. These private arrangements represented no great problem because the curricula were planned to fit those of the cooperating engineering college. Furthermore, these liberal arts colleges were well established institutions with a background and experience in administration and teaching at the collegiate level. This situation is similar to the normal arrangement among the municipal colleges of New York City. Successful pre-engineering students regularly transfer to The City College after a year or two in their borough liberal arts colleges.

On the assumption that these individual arrangements would not provide adequate opportunities for qualified applicants, the State Education Department, acting for the colleges of the state, sponsored the creation of a new temporary emergency institution under the title of The Associated Colleges of Upper New York. The funds for converting and equipping buildings were provided by the state. The Federal Government provided three abandoned military establishments and some assistance in securing equipment and house facilities. The corporation was put in the hands of 18 presidents of New York colleges as trustees. Ten of the 18 trustees preside over institutions including engineering schools.

Three campuses were established under a common administration and with common curricula in Liberal Arts, Business Administration, and Pre-Engineering. Champlain College is at Plattsburg, Mohawk College at Utica and Sampson College at Camp Sampson near Geneva. Later the Middletown Center was added under the management of Fordham University. The State's investment in these institutions will probably exceed $10,000,000.

How an administrative and teaching staff of 550 were assembled, and 6000 students admitted, and the plant made ready to receive them in a matter of about two months has been widely told. It was a remarkable feat of administration and organization.

The original enrollment in Sept. 1946 included about 2300 pre-engineering students. It was estimated, upon the basis of surveys made soon after the first term got under way, that about half of these students might eventually be candidates for transfer at the end of the two year course. It was further assumed by the administration of the Associated Colleges that transfer opportunities would be provided by the colleges of the State. In view of the fact that the engineering colleges had not been consulted relative to curricula or admissions policies there was for a time some uncertainty as to how these transfer opportunities would be provided.

The Association of Engineering Colleges of New York State took the

initiative in clearing up this uncertainty by joining in the survey which culminated in the report by Dean Hammond. Dean Ray Palmer Baker of RPI represented both state and national bodies in this survey. Visits to the campuses by a committee of inspection resulted in a report to the effect that the organization and facilities of the Associated Colleges of Upper New York were such as to make possible the production of graduates worthy of consideration for transfer to the engineering colleges of the State.

The members of the Association of Engineering Colleges were canvassed with a request to subscribe to a quota estimated to cover the number of eligible candidates for transfer in June 1948. As a result of this canvass, it was found that places would be available for 1000 transfers as of June 1948 provided that many acceptable candidates presented themselves, and provided they fit perfectly the pattern of curriculum choices required by the colleges.

The Associated Colleges were notified of this development and a joint committee of the Associated Colleges and the Engineering Colleges was set up under the chairmanship of Prof. Harold Bibber of Union College, to explore in detail the curriculum choices of the students and the distribution of available space. The committee was also asked to find the best means for bringing together the candidates for transfer and the colleges of their choice so as to avoid as much wasted effort as possible and to save the boys from the frustration and disappointment involved in making the weary rounds of the college admissions offices—an experience through which many of them had already passed.

It is explicitly understood, however, that the committee and the Association of Engineering Colleges can only expedite and organize this contact. Each college will apply its own criteria for admission and transfer. An effort will be made, however, to arrive at an agreement as to minimum standards on which application for transfer shall be encouraged by the Associated Colleges. These standards are concerned more with the quality of the student and his work than with the fitting of specific prerequisites because the Associated Colleges are in a position to vary the program of the last semester to meet these requirements and the engineering colleges are prepared to provide summer courses for the same purpose.

The entrance requirements of the Associated Colleges and their pre-engineering curricula were designed to correspond to an average of those of the engineering colleges. Qualitatively, the admissions policy of the Associated Colleges seems to have been rather liberal in terms of present day engineering college standards. However, a great deal of refresher work and special instruction was provided. The drop-outs and failures were heavy during the first year. It remains for other criteria to determine fully the quality of the product to be presented for transfer next spring. There is no question but that the candidate rejected by the engineering college in September 1946 who presents himself for transfer to junior status in September 1948 will receive careful scrutiny. Hence, it is proposed that the Sophomore Achievement Test should play an important role in the plan. Since a majority of the Engineering Colleges in the State will be using this test next spring, it should serve to bring the picture into clearer focus.

It is planned that the records of candidates recommended for transfer be sent first to the colleges of the student's first choice. Those not tentatively accepted will be forwarded to the second choice institutions and possibly to the third. A series of interview days are contemplated at the campuses of the Associated Colleges. These operations will result in bids from the colleges of the State.

Although this procedure is expected to discharge the obligation of the Engineering Colleges of New York State, it can not solve the whole problem because many of the first choices on the part of the students lie outside of the State. For these, of course, the Association of Engineering Colleges of New York State can make no provision except to urge the Sophomore Achievement Test as a means of establishing a basis of judgment with the widest recognition and acceptance for a situation of this kind.

The problem of the absorption of qualified transfers in New York State does not now appear as difficult as it did a year ago when it first came to the attention of the Engineering Colleges. At that time, it was expected that the 2300 students registered might yield over 1000 candidates for transfer. Now it appears that less than 1000 students will finish the two year program in pre-engineering next June. Of this number it is confidently expected that the Engineering Colleges of the State can absorb their share of qualified candidates for transfer. Perhaps there is after all a Providence that looks after engineers who "view hopefully the achievement of the impossible."

Division Activities

The mid-winter meeting of the **Division of Engineering Drawing** was held in Detroit on Saturday, December 27, in the Rackham Educational Memorial Building, with Wayne University and the University of Detroit as host institutions. Mr. A. B. Grisinger, of the Kaiser-Fraser Corporation, spoke on "Body, Art and Styling" and Mr. J. R. Holmes, of the Chrysler Corporation, gave a talk on "Chassis Design and Development." Professor R. R. Worsencroft, of the University of Wisconsin, presented the college viewpoint in a paper entitled "Shall We Give College Credit for High School Drawing?" Three McGraw-Hill sound motion picture text-films were shown, illustrating "The Drawings and the Shop," "Sections and Conventions" and "Selection of Dimensions." The Drawing Division dinner was featured by Professor F. G. Higbee, of the State University of Iowa, who gave an inspiring address on "Humanistic-Cultural Contributions Associated with Engineering Drawing." The mid-winter meeting was attended by 77 persons.

Control of the Tangible Factors of Engineering Education

By G. C. ERNST

Associate Professor of Civil Engineering, University of Nebraska

The November, 1947, JOURNAL of the Society carried the announcement of the resumption of ECPD accrediting of engineering curricula. It is important to note that "the ECPD has no desire or authority to impose any restrictions or standardization upon engineering colleges. In fact, it is a stated policy of the ECPD to avoid rigid standards and to encourage well planned experimentation." That this policy is a sound one and should be maintained cannot be truthfully denied. The fear of standardization, expressed throughout all reports on engineering education of the past quarter century, is a just fear. Standardization, alone, can kill initiative, prevent progress, and inhibit intellectual growth and advancement. It is equally true, however, that unbridled experimentation can lead to the exploitation of individuals and the abuse of the privilege of freedom. The ECPD, by specifying that educational experimentation be "well planned," admits the need for control.

The freedom for experimentation is admittedly necessary, but "the price of freedom is eternal vigilance." When circumstances and conditions become so complex, in any human endeavor, that they prevent mankind from stepping above a situation to view it in its entirety, while still retaining proper control of details, standards become necessary to maintain the vigilance of the individual or group. Control is thus developed and used, by means of standards and specifications, in technical engineering work. It has been a peculiar characteristic of the engineering educator, particularly those in policy forming groups, to fear standardization of the tangible factors of education, while at the same time teaching the value of standardization to students in engineering.

Insofar as engineering design is concerned, we are confronted on all sides by apparent restrictions of our freedom to experiment. Yet in the field of structural design alone, allowable stresses in steel and concrete have been increased approximately 25 per cent in the past twenty-five years. Can we claim an equivalent improvement in engineering education for the same period?

The complexity of the relationships between the various educational factors has been given as a primary reason for being unable to define limits for them. I question if the complexity is any greater than that found in the establishment of a control for structural design. As engineers, we have always sought out and established, by experimentation and experience, standards and specifications for the guidance of the profession. At the same time, we have retained the professional privilege of frequent re-evaluation of such controls, in order to utilize the results

of research and industrial development as they become available. Perhaps our technological advancement would have been sounder and more rapid without "standardization," but I doubt it. When it is said that *"well planned* experimentation" in education should be encouraged, only the need for control has been expressed, and it still remains to establish the standards of quality desired.

In my opinion, the most important tangible factors of engineering education needing control, in order to meet similar exigencies, are (a) the instructional cost index, (b) the laboratory area per student, and (c) the students per instructor, as discussed and analyzed in "Present Status and Trends of Engineering Education" by D. C. Jackson, published by ECPD in 1939. That quality control on these factors should be proposed as standards by policy forming groups seems just as logical to me as in the case of the tangible factors of engineering design. That such standards could not, in themselves, produce better schools is evident, but they would serve as an aid in preventing poor schools.

Of the three factors listed, the ratio of students to full time instructor is probably the most tangible. The trend of this ratio during the past two decades does not appear sound. Median values for this ratio, as obtained to the best of the writer's ability, are listed below:

Certainly, it cannot be denied that the overall teaching load to which a staff is subjected is a function of this ratio. That the relationship between this ratio and the size of school may not be linear should be equally evident. That we have engineering methods of analyzing such data for the purpose of establishing quality limits must be admitted.

Some of the questions that remain unanswered are: Does the ECPD approve of such a trend? Is it any more difficult to establish reasonable values for this factor than to determine a permissible stress for concrete of given proportions? Is our teaching becoming more efficient through the years or are we just more careless (or less vigilant)? *What is well planned* experimentation in engineering education?

As a group of individuals, generally eager to tackle and establish control of any problem from the theory of elasticity to flood flows, we seem peculiarly reticent about doing the same for our tangible educational problems. As civil engineers, we often speak of the ten per cent *chance* flood, but we could also speak of the ten per cent *chance* school of engineering. If the data on enrolment and teaching staff be analyzed as we frequently do for hydrologic data, the following interesting figures are obtained in table at top of page 466.

It may be noted that the 30 per cent chance institution from the ECPD data of 1936–1938 has become the 8 per

Year	Source	No. of Inst.	Students per Instructor (median)
1925	S.P.E.E. Report of 1923–29	76	15
1927	S.P.E.E. Report of 1923–29	119	13
1936–38	ECPD accrediting	125	18.5
1938	Personal investigation	110	20
1946	Personal investigation	95	29

Percentage of institutions having student-instructor ratios equal to or less than value shown below.	1	5	10	20	30	40	50	60	70	80	90	95	99
Stud./instr., ECPD '36–'38	8	9	10	12	13	15	17	19	22	26	33	39	54
Stud./instr., 1938	6	9	12	15	17	19	21	24	27	30	35	40	49
Stud./instr., 1946	9	12	14	18	21	24	28	32	36	43	53	62	83

cent chance institution of 1946. These values correspond to the 13 students per instructor that apparently existed in 1927 when the Board of Investigation and Coordination, in its conclusions regarding teaching staffs, reported that "the situation is quite satisfactory insofar as can be judged by statistics." It would seem that the remaining question might be: are we tossing the coin again in the accrediting program?

College Notes

Carnegie Institute of Technology will break ground for its new synchrocyclotron before the end of January, weather permitting, on the site of the former KDKA transmitting station at Saxonburg, Pa., 28 miles northeast of Pittsburgh, it was announced today by Dr. Robert E. Doherty, Carnegie president. In making public plans for construction of the new atom smasher, Dr. Doherty also announced the appointment of committees who will be responsible for various phases of the project. The Science Committee, under the chairmanship of Dr. Frederick Seitz, head of the physics department, includes Dr. Webster N. Jones, Director of the College of Engineering and Science; Dr. J. C. Warner, Dean of Graduate Studies; and Dr. Creutz.

An Institute for Effective Teaching has been established at the **University of Detroit** through the efforts of Dean Clement J. Freund, of the College of Engineering, as a means of aiding faculty members to give the maximum of instruction in the classroom. The Institute will have eight sessions, to be held once a month, with four lectures and four discussion groups. A member of the faculty will speak at each session, including: An Introduction to Effective Teaching, Effective Teaching, The Harassed Teacher, and Teaching as an Art.

Dr. J. C. Warner, Professor and Head of the Department of Chemistry and Dean of Graduate Studies at **Carnegie Institute of Technology**, has been appointed as an assistant director of the College of Engineering and Science, President Robert E. Doherty announced today. Dr. Warner, who will continue as head of the Chemistry Department and of Graduate Studies, will "direct, summarize the results of, and interpret such surveys and studies as are necessary to determine the future financial needs of the College and the equitable distribution

(*Continued on page 490*)

Unit Process Fundamentals

By CHARLES H. PRIEN

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Summary. Past instruction in organic unit processes has been characterized by the presentation of a vast number of "case studies" of industrial manufacturing methods, appropriately sub-divided into various broad classifications on the basis of the *major* chemical reactions involved. Because of the inadequacy of the data available, little attempt has been made to correlate the many physio-chemical factors which influence these chemical changes, with industrial practice.

In the light of recent advances in physical chemistry and physical-organic chemistry, a more *fundamental* approach to the unit process concept is warranted. It is suggested that a study of the basic laws governing the structure of matter, chemical equilibrium, and kinetics should constitute the initial course in Unit Process Fundamentals. Following this, a second course, "Industro-Chemical Constituents," in which the major non-chemical industrial factors are discussed, is deemed advisable. Finally, a methodical consideration of selected industrial processes, according to their Basic Process Factors involved, in which the principles presented in the preceding courses are applied, is proposed. A detailed outline of a suggested sequence of study is given.

Introduction

During the past several decades industry has demanded increasingly higher standards in the formal training of the chemical engineering graduate. This has resulted in a trend toward specialization in chemical engineering instruction. As was pointed out in a previous symposium,[15] this specialization has followed two paths of evolution—specialization according to fundamental concepts, and specialization for specific industries. The first of these branches has resulted in the "unit concept," which has revealed its unquestioned utility primarily in the separation of the physical functions of chemical engineering into a series of so-called "unit operations." The second branch has unwittingly been the progenitor of much present instruction in "industrial chemistry."

The successful application of the "unit concept" to the physical operations has fostered a feeling that the chemical changes occurring in an industrial manufacturing process could also be departmentalized, and grouped together under a classification to be known as the "unit processes." This trend in thinking has subsequently been reflected in the official definition of chemical engineering, as a[8] "coordinated series of unit *physical* operations and unit *chemical* processes."

Following this line of thought, therefore, an attempt has been made over a period of years to arrange the vast accumulation of facts and principles regarding the chemical phase of the process industries, into a series of functional categories based essentially upon a common type of chemical reaction. It has been heartening to note the adaptability of the organic chemical

industries to this treatment. Its extension to the inorganic field, while appearing more difficult, nevertheless has held promise of eventually being successfully accomplished also.

The postulation of a "unit process," equivalent in its fundamental relation to chemical changes in industry, to the unit operation and the physical changes, however, immediately raises two questions of interest:

(a) Do unit operations and unit processes together represent all major factors influencing the successful translation of a chemical reaction to profitable commercial practice? and

(b) Does the grouping of industrial chemical reactions according to the major chemical changes occurring therein, lead to quantitative laws of the same general applicability within each group, as those found for the unit operations?

A positive answer to each of these is necessarily inferred if, in the first case, the unit operations and processes together embody the field of chemical engineering; and if, in the second case, the unit process is equally as fundamental a concept as is the unit operation.

The necessity of considering the influence of such less clear-cut but equally real factors as corrosion, instrumentation, safety, labor, and the problems of industrial process economics, immediately suggests a negative answer to the first query, if the unit processes are to be concerned solely with the chemical changes of industry.

The second question is in reality a challenge as to the fundamental nature of the unit process concept. The critics of this hypothesis offer somewhat well-deserved argument in opposition to it, by pointing out the manifold difficulties encountered in drawing any but the most general criteria and restricted empirical relationships from its adoption. It is claimed, admittedly with a great deal of just cause, that the advantages of the unit process concept are primarily of a qualitative rather than a quantitative nature, and that, at best, it offers only limited correlative powers within any given process, *e.g.*, oxidation, nitration, hydrolysis, etc.

This criticism is admirably aided by the "present state of the art," *i.e.*, the lack of indisputable laws of the simplicity and comprehensiveness of those which characterize many of the unit operations.

In steady-state heat transfer, for example, Q equals $UAdT$, but the prediction of a reaction rate or equilibrium is often not characterized by either such simplicity, or such clear-cut, unqualified mathematical statement.

A further blow to the "fundamental concept" argument is the fact that, as now defined, unit processes necessarily include certain of the unit operations; for, as Shreve has stated,[11] "In unit processes . . . many of the unit operations function as an integral part of the chemical change." Thus, an overlapping in function between the two fields is obviously in evidence.

In an attempt to include all major chemical engineering industrial operations within the two unit concepts, recourse has been made to the utilization of broad definitions in describing the unit processes. Thus, Groggins has said,[5] "The unit process is used here to represent the embodiment of *all* the factors in the technical application of an individual reaction in organic synthesis"; and Shreve has described them[13] as "the commercialization of a chemical reaction under such conditions as to be economically profitable."

Neither of these definitions establishes those concise boundaries and indisputable areas so desirable to the technically-trained mind. This, however, is an inevitable outgrowth of the inclusion of so diversified a group of constituents, within a single framework.

The lack of fundamental laws, mentioned above, has, it is thought, been primarily the result of insufficient data and incomplete research in the fields of inorganic, organic, and physical chemistry, and would, it is felt, disappear as greater insight into these sciences is acquired.

Proposed Revision in Instructional Methods

It appears to the author that considerable clarification in presentation could be attained, if serious thought were given to separating the two aspects of the unit processes just described—namely

(a) that of a fundamental concept similar in scope to the unit operations, but concerned with the chemical factors of chemical engineering; and
(b) that of an "envelope" enclosing "all the factors in the technical application of an individual reaction.

This separation seems desirable because of the divergent nature of these two ideas.

In the first case attention is devoted to the basic phenomena of physical chemistry—reaction rates, equilibrium, and phase relationships—and to the structure of matter. In the second case, however, the less definitely predictable influences of such dissimilar entities as economics, safety, labor, etc. are introduced for discussion. These latter demand a totally different approach for their evaluation, and are, it is suggested, best considered separately from the basic physio-chemical laws.

It is proposed, therefore, that the program of instruction in unit processes be divided into the following three general categories, to be presented in the sequence shown below:

(a) A course study in "Physio-Chemical Fundamentals," covering the basic laws of chemical reaction and chemical structure;
(b) A background course in "Industro-Chemical Principles," in which a general discussion of instrumentation, materials of construction, safety, labor problems, and process industry economics is presented;
(c) Finally, a study of the major "Chemical Process Industries," in which the general principles presented in the preceding two sections are correlated and applied to specific industrial reactions. For this purpose, each industrial process is broken down into a series of so-called "Basic Process Factors" (see below).

In the subsequent discussion, these three categories are outlined in more detail, and the advantages of this method of treatment, particularly from the instructional viewpoint, are given. The outlines shown are complete only as to their skeleton framework, the subjects sub-listed under each section being intended as typical of those to be presented therein. It is presumed, of course, that advanced courses in both chemical engineering thermodynamics and unit operations are to accompany, if not even precede this program.

I. Physio-Chemical Fundamentals

The Physio-Chemical Fundamentals can be briefly summarized as the basic laws governing (a) the structure of matter, (b) chemical equilibrium, and

(c) kinetics. These are presented under parts A, B, C, and D of the outline shown below. It is these principles which Shreve has referred to when he expressed the conviction that [12] "some of us think it is possible to expect eventually to have data and formulae on which to base definite predictions concerning the quantitative course of reactions." While the initiation of the above program with a study of these principles is not to be construed as a conviction that this millennium has at long last arrived, it is based on a distinct feeling that sufficient data have now been amassed to furnish a more quantitative picture for the course of many chemical reactions.

Outline of a Course in Physio-Chemical Fundamentals

A. Chemical Properties and Chemical Constitution

I. *General Considerations on Structure*

(a) Electronic configuration of atoms
1. Atomic structure
2. Valence

(b) Electronic configuration of molecules
1. Ionic and covalent bonds
2. Coordinate bonds
3. Hydrogen bonds
4. Resonance and resonance energies
5. Free radicals
6. Bond distances, bond angles, bond energies

(c) Isomerism
1. Structural isomerism
2. Tautomerism—relation to hydrogen bonds
3. Stereoisomerism

(d) Conjugation
1. Aliphatic systems
2. Aromatic ring systems
3. Heterocyclic ring systems

II. *Structure of Aromatic Compounds*

(a) General considerations
1. Conjugation and resonance
2. Single and polycyclic systems

(b) Aromatic substitution
1. Electronic theory and the directive influence of substituent groups, dipole moment, etc.
2. Nitration and sulfonation reactions
3. Halogenation and Friedel-Crafts reaction
4. Special cases—diazotization of phenols and amines, non-catalytic halogenation, etc.

III. *Structure of Aliphatic Compounds*

(a) General considerations
1. Conjugation
2. Isomerism

(b) Double bonds
1. Ethylenic
2. Carbonyl

(c) Reactions of aliphatics
1. Nitration
2. Oxidation
3. Alkylation
4. Isomerization
5. Halogenation

IV. *Structure of Inorganic Compounds*

B. Physical Properties and Chemical Constitution

I. *General Considerations*

(a) Additive properties
(b) Constitutive properties
(c) Colligative properties
(d) Forces between atoms, molecules, ions
1. Van der Waal forces
2. Dipole forces
3. Repulsive forces
   a. Internal pressure
4. Hydrogen bonds
5. Covalent bonds

II. *Primary Properties in Relation to Structure*

(a) Phase relationships
1. General considerations of one, two, and three component systems, phase diagrams, etc.
2. Melting and boiling points
   a. Influence of intermolecular forces, crystal lattice, molecular shape, polarity
   b. Group contributions and isomerism
   c. Methods of measurement
3. Vapor pressure and solubility
   a. Ideal solutions and deviations therefrom
   b. Influence of hydrogen bonds
      1. Classification basis for liquids
      2. Constant boiling mixtures
   c. Influence of internal pressure
   d. Influence of polarity
   e. Methods of measurement

(b) Viscosity
1. Additive and constitutive influences
2. Correlation with vapor pressure
3. Methods of measurement

(c) Surface tension
1. Influence of intermolecular forces
2. Methods of measurement

III. *Secondary Properties in Relation to Structure*

(a) Refractive index
1. Influence of polarizability and arrangement of molecule
2. Methods of measurement

(b) Dipole moments
1. Influence of polarization
   a. Electronic polarization
   b. Atomic polarization
   c. Orientation polarization
2. Methods of measurement
   a. Dielectric constant
   b. Molecular beam
3. Vector addition of bond moments

(c) Molecular spectra
1. Moments of inertia and vibrational frequencies
   a. Relation to heat capacity and entropy
2. Raman spectra
3. Infra-red absorption spectra
4. Visible and ultra-violet absorption spectra
5. Methods of measurement

C. THERMODYNAMIC PROPERTIES AND CHEMICAL CONSTITUTION

I. *Thermochemical Properties and Structures* (F, S, dH, C_P)

(a) Thermal effects and physical change
1. Heat capacity of gases, solids, and liquids
2. Heats of vaporization, fusion, transition

(b) Thermal effects and chemical change
1. Heats of formation, combustion, hydrogenation, etc.
2. Relation to bond energies and resonance energies
3. Estimation from group contributions

(c) Chemical equilibrium
1. The third law of thermodynamics
2. Entropies of organic and inorganic compounds
   a. Method of structural similarity
   b. Structure and vibration frequencies
   c. Estimation from third law
3. Influence of temperature
4. Effect of pressure
   a. Quantitative discussion of Le-Chatelier's principle

(d) Industrial applications to, ***e.g.,***
1. Alkylation
2. Hydrogenation
3. Cracking
4. Isomerization

5. Chlorination
6. Nitric acid production
7. Metallurgical processes
   a. Roasting of lead ores
   b. Purification of zinc concentrates

D. KINETICS OF CHEMICAL CHANGE

I. *General Principles of Isothermal, Homogeneous Reactions*
   (a) Mass action law
   (b) Variation of rate with concentration
      1. First order reactions
      2. Second order and higher reactions
      3. Reversible, simultaneous, and consecutive reactions, as related to above
   (c) Homogeneous reactions between
      1. Dissolved substances
      2. Gaseous substances

II. *The Temperature Coefficient of Reaction Rate*
   (a) General principles
   (b) Effect on equilibrium

III. *Activation Energies and the Activation Complex*
   (a) Monomolecular and bimolecular reactions
   (b) Chain reactions
   (c) Application to halogenation, vapor-phase nitration, etc.

IV. *Catalysis*
   (a) General mechanism and kinetic theory
   (b) Homogeneous and heterogeneous catalysis
   (c) Influence of promoters, carriers, poisons
   (d) Activity—influence of physical state, surface, geometry, etc.
   (e) Selective catalytic action in hydrogenation, alkylation, oxidation, isomerization, etc.

Structure of Matter

The subject material under the first of the three "physio-chemical" divisions, the structure of matter, can be conveniently considered under the two headings, "Chemical Properties and Chemical Constitution," and "Physical Properties and Chemical Constitution."

Under the first of these, attention is given to the electronic configuration of atoms and molecules; bond types, angles, distances, and energies; isomerism; conjugation; etc., in short, the basic chemical structural characteristics which distinguish compounds and predicate their reactions.

Under the second grouping, "Physical Properties and Chemical Constitution," a study is made of the forces between atoms, molecules, and ions, and an attempt is made to correlate these with primary and secondary physical properties. Phase equilibria are reviewed, and the principles described under the preceding section applied wherever possible, *e.g.*, the relation of hydrogen bonds to solubility and vapor pressure.

It is immediately realized that the above separation into physical and chemical properties is somewhat arbitrary. This is further emphasized in the subsequent section, which is concerned with so-called "Thermodynamic Properties" (free energy, heat capacity, heat of reaction, entropy), and with "Kinetics." While it must be admitted that an overlapping in function between all sections of the outline may indeed exist, it is felt to be an inevitable outgrowth of the fact that "all of these concepts are human inventions and have no absolute independent existence in nature."

Chemical Equilibrium and Reaction Rate

In sections C and D, on "Thermodynamic Properties and Chemical Con-

stitution" and "Kinetics of Chemical Change," respectively, attention is given to thermochemical effects in relation to physical and chemical change, the basic laws of kinetics and catalysis, and the importance of the "activated complex" in predicting reaction mechanism.

II. Industro-Chemical Constituents

The subject matter up to this point has been primarily theoretical; but the chemical engineer is "concerned with a world of physical reality in which the solutions he uses are far from ideal, in which association and catalytic effects are coupled with a multiplicity of side reactions." [3] It is therefore necessary that the above information be realistically correlated with current plant practice, and particularly with those miscellaneous, essentially non-chemical industrial factors which ultimately determine success or failure in the plant production of a chemical material.

Before applying the physio-chemical principles to individual processes, however, it would be advantageous to devote some time to an enumeration and general discussion of the non-chemical industrial factors. This is done in the second major section of the program, on "Industro-Chemical Constituents." It is suggested that these miscellaneous factors be grouped under the general headings Industrial Instrumentation, Industrial Corrosion (Materials of Construction), Industrial Safety, Industrial Labor Problems, and Industrial Economics for the Process Industries, as shown in sections B, C, D, E, and F of the outline below. The sequence suggested is arbitrary.

Outline of a Course in Industro-Chemical Constituents

A. General Considerations

I. *Operating Factors*

(a) Industrial instrumentation
(b) Industrial corrosion

II. *Personnel Factors*

(a) Industrial safety
(b) Industrial labor problems

III. *Economic Factors*

(a) Raw materials
(b) Production costs
(c) Markets
(d) Water-fuel-power
(e) Waste disposal
(f) Maintenance and repair
(g) Transportation and packaging
(h) Research

B. Industrial Instrumentation

I. *General Considerations*

(a) Classification by
  1. Function—balancing, indicating, recording, etc.
  2. Variable controlled—temperature, pressure, etc.

(b) Principal parts
  1. Primary element
  2. Indicator and recorder parts—scale, chart, etc.
  3. Controller parts—operating, actuating

(c) Properties and characteristics
  1. Measuring instruments—accuracy, sensitivity, etc.
  2. Recording instruments—pen friction, etc.
  3. Controllers—application lag, demand, period

II. *Types*

(a) Temperature instruments
  1. Thermometers, mercury, resistance, etc.
  2. Thermoelectric pyrometers
  3. Optical and radiation pyrometers

(b) Pressure instruments
1. Balancing type—manometers, balls, etc.
2. Elastic deformation type—Bourbon tubes, helix, etc.
3. Miscellaneous types—carbon piles, crystals, etc.

(c) Fluid flow instruments
1. Quantity meters—weighing, volumetric
2. Rate Meters—orifice, Venturi, nozzle, rotameter, weir, open and closed channel current meters, etc.
3. Pressure differential devices
   a. Indicating manometers—various types
   b. Recorders—mechanical and electrical types
   c. Integrating devices—mechanical, electrical

(d) Liquid level instruments
1. Visual indicators
2. Float-actuated recorders
3. Electrical-control indicators and recorders
4. Static pressure meters
5. Differential pressure meters

(e) Humidity instruments
1. Psychrometric type—atomizing, sling
2. Hygroscopic type—dimensional, gravimetric
3. Thermal conductivity type
4. Condensing type

III. *Automatic Control*

(a) General theory

(b) Classification of types
1. Two-position (on-off)
2. Proportional position
3. Floating control
4. Proportional plus floating (automatic reset)
5. Automatic reset plus second derivative

(c) Automatic control mechanisms
1. Self-operated
2. Servo-operated
3. Control valves

(d) Application to specific problems in process control

C. Industrial Corrosion (Materials of Construction)

I. *General Considerations*

(a) Factors affecting corrosion—film formation, passivity, etc.

(b) General types of corrosion

II. *Corrosion in the Absence of Water*

(a) Direct chemical attack of metals
1. Effect of foreign gases
2. Protective films
3. Creep
4. Effect of temperature

III. *Electrochemical Corrosion*

(a) Oxygen depolarization type
1. Influence of oxygen and of electrolyte
2. Solubility of anodic and cathodic products
3. Flowing solutions
4. Bimetallic couples
5. Metallurgical inhomogeneity
6. Interfering ions and molecules (inhibitors)

(b) Hydrogen evolution type
1. Factors affecting gas evolution at surface

IV. *Naturally-occurring Types*

(a) Atmospheric corrosion

(b) Corrosion in natural waters

(c) Corrosion in soils

V. *Corrosion Protection*

(a) Chemical methods

(b) Electrochemical methods

(c) Electrical methods

(d) Others

VI. *Materials of Construction*

(a) General discussion of applicability of specific
1. Ferrous metals and alloys
2. Non-ferrous metals and alloys
3. Inorganic non-metals
4. Organic non-metals

D. Industrial Safety

I. *Occupational Hazards*

(a) Dusts—alundum, glass, wood, flour, etc.
(b) Metallic poisons—lead, mercury, cadmium, etc.
(c) Toxic gases—chlorine, sulfur dioxide, etc.
(d) Toxic organic solvents—aliphatics, aromatics
(e) Protective equipment
1. Respiratory protection
2. Head and eye protection
3. Protective clothing

II. *Process Hazards*

(a) Flammable liquids and gases
(b) Explosive materials
(c) Spontaneous combustibles
(d) Compressed gases

III. *Physical Hazards*

(a) Building facilities
1. Construction features and arrangement
2. Fire protection
3. Lighting
4. Ventilation
5. Sanitation
6. Floors, platforms, stairs, ladders
(b) Equipment
1. Moving machinery guards
2. Safety devices on dangerous machinery

E. Industrial Labor Problems

I. *Historical Background*

(a) Origins of labor movement
(b) Development of present-day labor organizations

II. *Factors in Personnel Management*

(a) Wage agreements
(b) Working hours—overtime, shifts, vacations, holidays, etc.
(c) Working conditions
(d) Seniority
(e) Promotions
(f) Layoffs and discharges
(g) Financial incentives and profit-sharing

III. *Labor and the Process Industries*

(a) Manpower requirements of process industries
1. Classes of employment
2. Assessment against sales dollar
(b) Trade Union membership in process industries
1. American Federation of Labor
2. Congress of Industrial Organizations
3. Others

IV. *Problems in Industrial Relations*

(a) Employee representation
(b) Job protection—strikes, seniority, feather-bedding, etc.
(c) Effects of technological progress
(d) Others

V. *Modern Labor Legislation*

(a) A brief survey only

F. Industrial Economics for Process Industries

I. *General Discussion of Factors Involved*

II. *Raw Materials*

(a) Sources—mine, forest, farm, sea, air
(b) Geographical factors
(c) Purity
(d) Facts and figures for process industries

III. *Production Costs*

(a) Yields and by-products
(b) Distribution of sales dollar between raw materials, wages, depreciation, taxes, transportation, fuel and power, etc.
(c) Development costs

IV. *Markets*

(a) Chemical products for use
1. By final consumers
2. By non-chemical industries
3. By chemical industry itself
4. To round out established lines
5. As new class of products entirely

(b) Domestic vs. foreign markets
(c) Analysis by
1. Uses
2. Geographical areas
3. Seasons of year
(d) Price studies

V. *Water, Fuel, and Power*
(a) Water requirements
1. Uses
2. Purity and methods of purification
3. Availability
4. Needs of specific industries
(b) Fuel and power requirements
1. Uses
2. Sources—coal, gas, electrical energy, etc.
3. Relative costs
4. By-product power
5. Needs of specific industries

VI. *Waste Disposal*
(a) Types of waste
1. Organic waste
2. Toxic chemical waste
3. Inert waste
(b) Atmospheric and stream pollution
(c) Treatment
1. Mechanical methods—screening, sedimentation, etc.
2. Chemical methods—flocculation, neutralization, etc.
3. Biological methods—aerobic, anaerobic
(d) State and federal regulation

VII. *Maintenance and Repair*
(a) Rates of depreciation
(b) Survey of typical industries
1. Organic chemicals industry
2. Pulp and paper mill
3. Sugar refinery
4. Others

VIII. *Transportation and Packaging*
(a) Transportation
1. Methods—rail, water, highways, air
2. Cost allocation
(b) Packaging
1. Returnable containers
2. Non-returnable containers
3. Storage and stability problems

IX. *Research*
(a) Importance in process industries and relative position of these to all industry
(b) Costs—per cent of sales dollar
(c) General stages of process development
(d) Funtions of process research
1. Improve process and products
2. Develop new products and processes
3. Utilize by-products
4. Develop synthetic substitutes for natural products
5. Break monopolies

Industrial Instrumentation

The importance of instrumentation in the process industries warrants, it is believed, a brief consideration of the general principles of measurement and control, and of the five major classes of instruments encountered in chemical processing—temperature, pressure, fluid flow, liquid-level, and humidity indicators, recorders, and controllers. After a familiarity with these mechanisms has been attained, it is desirable that the general theory of automatic control be presented, together with the advantages and limitations of the major types of control, and their applicability to specific process control problems.[2,]

Industrial Corrosion and Materials of Construction

Although much general equipment design is stressed in the course in unit operations, insufficient attention is usually given therein to the effects of corrosion, and the choice of suitable materials of construction. In this section, therefore, the theory of corrosion is briefly outlined, together with the

mechanisms of the most common type encountered in industry—metallic corrosion.[1] The relative resistance of individual ferrous and non-ferrous metals and alloys, and the non-metals to specific chemicals is described,[9] and various methods of corrosion protection enumerated.

Industrial Safety

The very nature of the materials handled in the process industries lends emphasis to the importance of the problems of general safety and hygiene. These are discussed under three broad classifications—occupational hazards, process hazards, and physical hazards. The toxic and flammable properties of dusts, certain metals, gases, and solvents are mentioned, together with the necessary protective measures required in their handling. The section is concluded with a description of general safety practice in respect to physical facilities—buildings, machinery, etc.[4, 9]

Industrial Labor Problems

It is realized that the factors which are within the scope of this section, as is true of most of the factors discussed under the general classification "Industro-Chemical Constituents," are more properly the province of a specialist in this field. However, the extreme importance of labor problems in modern industry warrants, it is believed, their particular inclusion herein.

After a brief historical background of the rise of unionism in industry has been given, together with the underlying causes, the functions of modern labor unions are discussed. The relative manpower requirements of the process industries, particularly as to classes of employment, are reviewed, and a brief sketch of present-day trade union membership therein given. A survey of present-day problems in industrial relations, and of modern labor legislation then follows.

Industrial Economics for Process Industries

A wide variety of miscellaneous economic factors not elsewhere considered, is grouped together under this general heading. These have been sub-divided into nine parts—raw materials, production costs, markets, water-fuel-power, waste disposal, maintenance and repair, transportation and packaging, and research. An attempt is made under each sub-division to outline the principal factors influencing profitable industrial manufacturing insofar as this particular entity is concerned. The diversified subject matter and scope of the entire section effectively restrict the thoroughness of presentation. The utility of even a general discussion of each of these economic factors, however, in orienting the subsequent analysis of specific industries is sufficient justification, it is felt, for its inclusion.[6]

III. Basic Process Factors

Having imparted a sound background in physio-chemical principles, and in those miscellaneous non-chemical variables which together constitute the fundamental components of the process industries, it remains, finally to correlate these and apply them to specific industrial chemical processes.

It is in such correlative powers, of course, that the greatest utility of the present unit process concept has resided to date. The approach has been "gradually to accumulate related facts and principles in a given narrow field, from which we hope some day to lay down some useful formulations regarding the conduct of each unit process."[18] It would therefore be possible to pro-

ceed to a detailed study of each unit process, under the present classical headings—oxidation, sulfonation, amination, etc. Since the fundamentals have been advantageously individually considered separately in the program, however, without reference to any particular common chemical reaction (the basis of the unit process classification), little is to be gained by such a procedure.

A better approach, it is felt, is to retain the sub-division of the process industries according to their major industrial groups, *e.g.,* Phosphorus Industries, Dye Industries, etc. Each of the major chemical operations within a given industry can then be broken down into its "Basic Process Factors," which are essentially independent of the process under consideration. These Basic Process Factors, it is suggested, are (a) the mechanism of reaction, (b) the chemical reagents employed, (c) the physio-chemical phenomena influencing reaction, (d) the reaction products, their separation and purification, and (e) the miscellaneous engineering factors involved. The fundamentals learned in the preceding program of study can be applied to the case at hand, in their proper relation to the particular process factor under consideration.

A more detailed breakdown of the method is shown in the following outline. It might be pointed out that an approach to this mode of presentation has recently been made by Shreve.[14]

Outline of a Course in Basic Process Factors

(*Note:* For general application to each specific process)

A. General Considerations

I. *Mechanism of Reaction*

(a) General types

1. Addition, substitution, oxidation, reduction, polymerization, condensation, pyrolysis, double decomposition, etc.

(b) Free energy change

(c) Activated complexes

II. *Chemical Agents*

(a) Technical purity

(b) Sources, availability, cost

(c) Corrosive nature

III. *Physio-chemical Process Factors*

(a) Chemical factors

1. Thermochemical effects
2. Equilibrium
3. Reaction rate
4. Catalysis

(b) Physical factors

1. Temperature
2. Pressure
3. Solubility
4. Concentration
   a. Ratio reactants, etc.
5. Phase equilibria

IV. *Reaction Products*

(a) Effect of raw material purity

(b) By-product formation

(c) Separation and purification methods

1. Methods based on vapor pressure
   a. Distillation, etc.
2. Methods based on solubility
   a. Fractional crystallization
   b. Decantation
   c. Filtration
   d. Extractions
3. Miscellaneous methods
   a. Salt formation
   b. Others

(d) Yields

1. Conversions per pass
2. Factor affecting losses
   a. Side reactions
   b. Washings
   c. Spillage, etc.

(e) Properties and uses
1. Effect of structure on properties
2. Classification of uses

V. *Engineering Factors*

(a) Equipment
1. Materials of construction
2. Batch vs. continuous operation
3. Phases present
4. Instrumentation required
5. Unit operations employed
   a. Effect of heat transfer, fluid flow, agitation, etc. on design
6. Safety precautions
   a. Inflammability, explosivity, toxicity of materials present
7. Materials handling problems

(b) Labor requirements
1. Quality and cost
2. Availability
3. Supervision
4. Environment

(c) Economics
1. Plant location with respect to
   a. Raw materials
   b. Labor
   c. Service requirements—water, power, fuel
   d. Markets
3. Marketability
   a. Uses of products—present, potential
   b. By-product and waste disposal
   c. Competitive processes and products
   d. Patents—restrictions, protection

Such a mode of presentation serves, effectively, to point out both the basic physio-chemical phenomena governing the chemical reaction, and the equally influential miscellaneous industro-chemical variables, which together determine the manner in which chemical production is conducted on an industrial scale. It does so in an orderly fashion, with a maximum opportunity for inter-process correlation and comparison.

Rather than attempt to cover the process industries completely, it is sufficient to choose a selected group of "typical industries" each of which has certain outstanding characteristics, either of a strictly chemical or strictly industro-economic nature, or both, which are particularly peculiar to it.

In considering such organic fields as, for example, the Dye Industry, the nomenclature and classification of the present unit processes can well be retained, as an aid only, however, in separating the variety of chemical reactions to be found therein.

Because of the wide freedom in choice of suitable "typical industries," which is permissible to secure the ends desired, no attempt is made here to offer any rigid suggestions as to acceptable combinations.

Advantages of Program

Such a treatment of the whole unit process concept has four distinctly unique advantages:

1. Any technical chemical manufacturing operation, whether the end product is organic or inorganic, can be analyzed by this method.

2. It is not necessary, nor indeed particularly desirable to divide the process industries into such *chemical* classifications as nitration, oxidation, hydrolysis, etc. The primary need for such separation, *i.e.*, in order to divulge fundamental laws through the accumulation of related facts and principles, has been satisfied elsewise.

3. The various manufacturing groups —*e.g.*, the synthetic fibers industry, the nitrogen industry, etc.—can be retained intact and considered in an advantageous sequence more in keeping

with their realistic relative position in the industrial economic structure.

4. Finally, the sterility which has, according to a number of critics, crept into chemical engineering education as the result of the "unit concept" in general, and which, it is claimed, tends to divorce it from its primary purpose, the study of profitable industrial application of *chemical* reactions in order to produce *chemical* products, is thereby effectively combated.

Conclusions

In conclusion, therefore, it is pertinent to summarize briefly the major theses presented above. These are as follows:

1. The unit chemical processes cannot be considered in the same fundamental sense in which we speak of the unit operations. There are certain physio-chemical phenomena, however —the basic relationships of the structure of matter to the chemical and physical properties of compounds; and the laws of chemical equilibrium and kinetics—which govern the chemical phases of any industrial process, just as do the principles of the unit operations the physical phases. It is these physio-chemical principles which are, in reality, the fundamentals of the unit processes.

2. In addition to the physio-chemical phenomena, the unit processes include a group of miscellaneous "Industro-Chemical Constituents" of an essentially non-chemical nature, which are equally as influential in determining the success of commercial manufacture of a chemical product as are the physio-chemical laws. These constituents can be classified under the general headings instrumentation, corrosion, safety, labor problems, and process economics.

3. In any industrial chemical process, there are a series of common "Basic Process Factors" into which the process may be sub-divided, no matter what its nature or of what character its chemical products. These factors are conveniently considered under the five headings—mechanism of reaction, chemical agents employed, physio-chemical reaction influences, separation and purification of reaction products, and miscellaneous engineering factors.

4. Unit process instruction is best achieved by discussing, first, the physio-chemical fundamentals, and next, the general importance of the miscellaneous industro-chemical constituents, without particular reference to any given industry. Subsequently these principles can be applied to any industrial chemical process, by subdividing that process according to the basic process factors involved.

5. The accumulation of related facts and principles based upon a single type of chemical reaction, which has characterized unit process instruction to date, is of only limited correlative value, and tends to artificially segregate these reactions from their parent industrial economic structure. By utilizing the combination of initial course of study in physio-chemical fundamentals and miscellaneous industro-chemical components, with a subsequent application to specific industries by means of the basic process factors involved it is possible to retain, through sequence of presentation, the position and interrelationship of each reaction to its companions within a given process, and of that process to a given type of industry.

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Jet Propulsion Instruction and the Undergraduate Curriculum in Aeronautical Engineering*

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Introduction

Research and development activities conducted during the war years have culminated in bringing the following new engines into the aircraft propulsion field:

(a) the turboprop engine, which is a gas turbine power plant for propeller drive;
(b) the turbojet engine, which is a gas turbine power plant power plant which develops thrust by jet propulsion;
(c) the ramjet engine, which is a compressorless, continuous air flow, jet propulsion engine;
(d) the pulsejet engine, which is an intermittent firing, compressorless jet propulsion engine; and
(e) the rocket engine, which differs from all of the others in that it uses no atmospheric air in its operation. It is a jet propulsion engine utilizing the reaction of suitable chemicals carried in the rocket jet propulsion system.

Of the aforementioned power plants only the turboprop engine is a direct competitor of the piston engine, and then only in large power sizes; above 2,500 hp. approximately. The jet propulsion engines are power plants for achieving objectives unattainable with either the piston engine or turboprop engine.

Currently it appears that the piston engine propeller-drive will dominate the fields of small aircraft and moderate speed transports for many years to come. In the large airplane field, as cruising speeds are raised above 350 m.p.h., the turboprop engine is destined to become the dominate power plant. Thus, it is apparent that the turboprop engine is an important power plant for both civil and military aviation.

The jet propulsion engines, on the other hand, have great military importance today and little value in civil aviation. But, since the trends in aviation have always been to faster and faster aircraft, the importance of the turbojet engine to civil aviation will be an increasing one with time. It is fairly safe to state that there is no long enduring "status quo" in aviation.

It should be realized that the economic well being of the aviation industry is dependent to a great extent upon military expenditures. Consequently, judgments of the importance of aircraft propulsion power plants cannot be based on civil use only. Currently, the military expenditures for research and development of turboprop and jet propulsion engines greatly outweigh the like expenditures in the piston en-

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gine field. Consequently, the aviation industry as well as the various government agencies are seeking young graduate engineers who are equipped with fundamental knowledge pertinent to these new engines.

The foregoing indicates that the engineering colleges must be equipped to give instruction in these new power plant fields, and it appears that these fields will become more important as time proceeds. Two problems must be faced. The first, is to provide an undergraduate curriculum which enables the student who cannot go beyond the bachelor's degree to obtain a fundamental understanding of the operating characteristics of these engines. The second, is to provide a program of graduate instruction which will equip the student to undertake research and development work in the gas turbine and jet engine fields.

Gas turbines and jet propulsion engines are what might be termed fluid dynamical machines. Their analyses are based on such fundamental sciences as fluid mechanics, aerodynamics, thermodynamics, and thermochemistry. In those cases where the undergraduate curriculum in aeronautical engineering includes instruction in fluid mechanics, aerodynamics, and thermodynamics it may be feasible and even desirable to introduce a one-semester course devoted to Aircraft Gas Turbines and Jet Engines.

Any meritorious course of instruction in this field should be analytic in nature. Descriptions should be kept to a minimum. The emphasis should be on the fundamental aerodynamic and thermodynamic principles involved. The course should be conducted so that the student gives full use to the aforementioned sciences. A course of this character can have great value from a purely educational standpoint, apart from the information the student obtains regarding the power plants themselves.

It is conceded that the student cannot be given more than a fundamental understanding of the new power plants in the undergraduate curriculum, but this fundamental knowledge can be of great importance to the student who is unable to pursue graduate study. Accordingly, the undergraduate power plant option in Aeronautical Engineering, at Purdue University, includes a course entitled Gas Turbines and Jet Engines for Aircraft (Course AE 115) in the second semester of the senior year. This course is open to graduate students as well as seniors. The results, based on examinations, indicate that undergraduate students with adequate preparation in fluid mechanics and thermodynamics do fully as well as the graduate students.

An accompanying Laboratory Course (AE 117) is also available.

PURDUE UNIVERSITY

SCHOOL OF AERONAUTICS

COURSE AE—115

GAS TURBINE AND JET ENGINE POWER PLANTS FOR AIRCRAFT

TOPICS

Historical development of gas turbine power plant

Ideal open cycle gas turbine power plant non-regenerative and regenerative

Causes of departure of actual cycle from ideal cycle
- (a) compression process
- (b) expansion process in turbine
- (c) regenerator
- (d) combustion chamber
- (e) mechanical losses
- (f) parasite losses
- (g) variation of specific heat of working fluid

Performance criteria
air ratio
work rate

Simplified analysis of plant efficiency
(a) temperature at end of compression
(b) temperature at turbine exhaust
(c) heat supplied and plant efficiency
Test No. 1
Characteristics of gas turbine power plant (non-regenerative)
(a) effect of pressure ratio
(b) effect of intake air temperature
(c) effect of intake air density
(d) effect of compressor and turbine efficiencies
(e) effect of pressure losses
(f) effect of variable specific heat of working fluid
Place of the gas turbine power plant in aviation
Development problems and potentialities
Test No. 2
Momentum theorem applied to propulsion thrust development
Classification of types of thermal jet engines
(a) ramjet
(b) pulsejet
(c) turbojet
(d) probable speed ranges of application
Historical development of turbojet engine
Momentum theory applied to thrust development of turbojet engine
Propulsion power and propulsion efficiency for turbojet engine
(a) general equation for propulsion power
(b) general equation for ideal propulsion efficiency
(c) effect of velocity ratio
(d) thrust power vs. velocity ratio
(e) velocity ratio for maximum thrust power
Cycle analysis of turbojet engine assuming perfect gases
Performance parameters vs. inlet mach number
Performance parameters vs. inlet mach number
Test No. 3
Performance characteristics of turbojet engine
General equations for gas flow through nozzles and diffusers
Flow of gases through converging nozzles
Flow of gases in subsonic diffusers
General flow conditions for turbojet engines
Design features and descriptions
Combustion problems in turbojet engines
Flow and pressure loss in combustion chamber
Test No. 4
Elementary theory and characteristics of centrifugal and axial flow compressors
Test No. 5
Elementary theory of turbines
Test No. 6
Elementary theory of ramjet engine
Performance characteristics of ramjet engine
The pulsejet engine and its characteristics
Test No. 7
Interior ballistics of rocket motors
Performance criteria for rocket motors
The liquid propellant rocket motor
Application of rockets
Test No. 8

Professional Advancement in Canada*

By C. R. YOUNG

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Prior to confederation of the Canadian provinces, in 1867, there was so little employment for engineers in Canada that organized attempts to promote the advancement of the engineering profession made but scant headway. The first sustained effort in this direction came with the establishment of the Canadian Society of Civil Engineers, in 1887. The Engineering Institute of Canada, with its broader interests and wider scope, has since 1918 carried on and vastly extended the activities of the parent society from which it sprang.

Early in the nineties sustained agitation developed for the constitution of the profession in Canada as a closed corporation, analogous to those of law and medicine. In 1892, Alan Mac dougall, one of the far-seeing and resolute engineers who had taken part in the establishment of the Canadian Society of Civil Engineers, presented to the Society a notable paper on "The Professional Status." It was a classic. In it were challengingly set out most of the concepts and arguments that still engage the thought of those who concern themselves with the matter today.

The discussion bore fruit. Drafts of acts for the provincial incorporation of engineers were prepared. According to the terms of the British North America Act, which constitutes whatever of a written constitution Canada possesses, legislation controlling engineering practice is a matter for the provinces rather than for the Dominion. Proceeding in conformity with this, the members of the Canadian Society of Civil Engineers in Manitoba succeeded in obtaining legal recognition of engineering as a profession in that province by the enactment of the Manitoba Civil Engineers Act of 1896. Here, as elsewhere in Canada at that time, "civil engineering" was deemed to comprehend all engineering that was not military. Quebec followed suit in 1898.

Proving difficult of operation, these acts were superseded in 1920 by improved acts administered respectively by the Association of Professional Engineers and the Corporation of Professional Engineers. In comparatively rapid succession all the remaining provinces, except Prince Edward Island, which by reason of its smallness has few engineers, have enacted restrictive legislation.

While marked benefits to the public, as well as to engineers themselves, have been derived from the licensing movement, one undesirable consequence has followed in its train. Far too many young men have come to assume that the only thing lying between them and full professional stature is the obtaining of the legal right to practise. Nothing could be more

*Address delivered at the Montreal meeting of E.C.P.D.

illusory. There is no assurance whatever that one so equipped will necessarily be accepted by a discerning and critical public as a person fully entitled to the esteem and deference that by common consent are accorded the members of the older and so-called learned professions. One illiterate or boorish licence-holder may offset in the public mind the merits of a score of others about whom there can be no question. The whole profession is comprised by the unacceptable few.

Not enough weight has been given to general education by either the professional schools of engineering or the licensing associations. Two screens in tandem should be placed in the educational and training stream. The first would function as a selective device to ensure, in so far as may be possible, that those who enter the professional schools have those humanistic and cultural interests and capacities that must be inherent in one who hopes to be accepted as a member of a true profession. The second should be introduced by the licensing bodies in scanning applications for registration as a check on the effectiveness of the first as an instrument of selection of personnel for educational and professional training and as a corrective if it has failed.

Faculties and colleges of engineering ought to revise sharply upward their general educational requirements for admission, so that the twenty-five per cent or so of young men who should remain in technical institutes or secondary vocational schools are kept there and are not permitted to impede the programs of the professional schools. Far better work could be done in the latter and the quality of their output made the more impressive if they were not required, under circumstances presently existing in Canada, to superimpose on true collegiate work the added task of dealing with the area of education that lies between the secondary schools and the universities. Those whose talents and interests definitely belong to this zone are for the most part unpromising aspirants for full professional qualification.

On their part, the licensing bodies should place increasing emphasis on the general educational attainments of those who seek registration. There are still substantial numbers of applicants who base their claims almost wholly on technical knowledge and competency and but little on acquaintance with those things that characterize a broadly educated man. As a result of undue emphasis on the importance of excellence in mathematics and science some men of circumscribed outlook have unfortunately slipped through the universities with small evidence of ability to express themselves clearly or correctly in their own language. The proposed second barrier against illiteracy in professional circles could be introduced by the licensing associations through requiring, in respect of the graduates of the professional schools, a minimum standing in non-technical subjects and through a corresponding test of those who seek registration through examination.

It is unfortunate that some young men look to the professional associations to do for them what only they can do for themselves. Attainment of that degree of public regard, which in effect accords to the one that prompts it a vital place in the community wherein he labors, derives from the personal merits of the man himself and not from the bulk or the forcefulness of any organization to which he belongs. One cannot be securely legislated into

high places. Professional organizations have a value that is largely limited by technological and economic considerations. They cannot give that quality of understanding, that sympathetic man-to-man relationship which determines ultimate acceptability.

Efforts of the Canadian Professional Organizations

It would be unfair to say that engineering organizations in Canada have been unaware of this fundamental principle. They are doing much to raise the quality of the profession by directing into it young men of the highest personal promise and correspondingly by exclusion of those that are unsuitable. They no longer rest their labors on the promotion of technical knowledge and competency. The development of the engineer as a person bulks large in the policies of all of them. No longer is it merely a matter of producing annually an output of human problem-solving machines in quantity gauged to the supposed demands of industry.

Such selection of engineering students as is possible through counseling and guidance programs has progressed notably in the past few years. Through its Committee on the Training and Welfare of the Young Engineer, established in 1939, the Engineering Institute of Canada has set up counseling committees in its various branches across the country. Growing out of this, the Canadian Committee for Student Guidance in Science and Engineering, composed of representatives from the Canadian Institute of Mining and Metallurgy, the Chemical Institute of Canada, and the Engineering Institute of Canada, was set up and has expanded the original effort.

These Committees have served a double purpose. They have drawn to the attention of young men who were contemplating engineering careers the requisites for success in such callings and have diverted into other fields those who gave little promise of success in the engineering field. At the same time, prospective students have been shown, and the news travels fast, that many senior members of the profession are interested in the personal fortunes of those who seek entrance to it. Identification of eminent practitioners with the interests of oncoming youth is an asset on both sides.

Extension of guidance service to young engineers subsequent to graduation is being planned. Formal machinery providing sponsorship of each graduate by an experienced engineer does not appeal particularly to young Canadians, but they do appreciate and welcome the informal fraternization and encouragement that comes naturally when senior engineers mix in meetings and gatherings with those who have most of their careers before them.

Although no formal steps have as yet been taken to set up a system of accrediting of the professional schools of engineering in Canada, there is little doubt that this will be undertaken in the not too distant future. A suitable mechanism would appear to be through the Committee on Applied Science and Engineering Education of the National Conference of Canadian Universities. This Committee, organized in May, 1946, had an excellent first meeting on the occasion of the annual Conference in May, 1947. It is composed of one representative from each of the member universities and colleges of the Conference offering engineering instruction at the university level. The

desirability of making an early study of accrediting in Canada will be drawn to the attention of this Committee as soon as its 1947–48 organization is completed.

No organized measures for direct promotion of professional recognition in Canada have been devised. Individual members of the profession have, however, come into high and well-deserved prominence, not only through wartime activities, but in peaceful pursuits as well. One might cite the outstanding record of the Right Honorable C. D. Howe, Minister of Reconstruction and Supply, born an American, who before entering political life headed a highly successful firm of consulting engineers. General A. G. L. McNaughton, now President of the Atomic Energy Control Board of Canada and Chairman of the Canadian Delegation to the United Nations Atomic Commission, bears a responsibility that not only confers an honor on the profession in which he was trained, but places Canada immeasurably in his debt. Dr. C. J. Mackenzie, President of the National Research Council, has provided an illustration of the power of an able and resourceful engineer in directing the programs of a great scientific agency. The bench is honored by men who were trained as engineers and do not regret that approach. One such is the Honorable Mr. Justice R. E. Laidlaw, of the Appellate Division of the Supreme Court of Ontario. Diplomacy has made its bid, too, for the services of those with technological training. Mr. C. Fraser Elliott, an able Deputy Minister of the Department of National Revenue, has now become the Canadian Ambassador to Chile.

It may appear strange that those members of the engineering profession who most frequently come into public notice are those who have moved over into other fields as a result of the capacity that they displayed while ranked amongst the engineers. Doubtless this is due to the fact that in public capacities they deal much more frequently with persons than they do with things and become more widely known for it. It might also seem that the most effective approach to national eminence on the part of the engineer is to conduct a flank movement through territory traditionally occupied by members of other professions and callings.

Resistance to Professional Advancement

Long-seated resistances to the new and broader concept of engineering as a learned profession, with all that the term connotes, still confront those who labor for its realization. One can scarcely wonder at their existence when it is remembered that in English-speaking countries, up to a century and a quarter ago, men prepared themselves for engineering tasks and responsibilities in the same manner as they had from the dawn of history. They learned by trial and error, by observation, practice, and apprenticeship. The English millwrights—all honor to their sturdy enterprise and resourcefulness—were but uneducated workmen with little or no thought of a higher status. James Brindley, the man who developed the great inland waterways system of Britain, could scarcely read or write and was content to receive throughout his amazing career no more than the wages of a skilled mechanic. George Stephenson and Thomas Telford began similarly, but, although achieving more exalted heights of pro-

fessional prestige, they and those that followed them during many succeeding years in Britain regarded apprenticeship as the only satisfactory means by which one could become an engineer.

The things worth knowing being therefore conceived of those that could only be acquired by operations in the shop and field, it is not strange that little thought was given to the more polite forms of learning, such as are prized by men who excel in other professions or in public life. The concept of engineering as no more than a superior trade persisted and remnants of it still remain to plague those that strive for something more.

Ignorance of what men in other walks of life think or do has bred narrow intolerance in many of those who cling to the old attitudes. Knowing little of others who live and work in spheres very different from their own, they are disposed to belittle and suspect them, as the south Englanders did of the men of the north in the days before the improvement of transportation made contacts easy and frequent.

Even in these days which we euphemistically term enlightened there are many young men seeking entry to the universities who think only of the mastery of an intricate trade, the acquisition of a few scientific or technical tricks which will make them superior to their less practical fellows and give them an easy and secure livelihood unattended by any obligation to pull their own weight in the social, humanistic and political efforts of their time.

Some Suggested Measures

While unstimulated awareness of the superior advantages of the well-educated man as contrasted with one of narrow outlook may bring eventual but slow remedy, educational institutions and professional organizations cannot allow the matter to rest there. Positive and definite action needs to be taken.

On their part the professional schools of engineering should revise upward their standards of admission, at least in so far as general educational subjects are concerned. For example, a bare pass or credit in English ought not to be accepted. A man who is so deficient in the use of this mother tongue as to be wrong as often as he is right in the use or appreciation of the spoken or written word is a sorry prospect for profession eminence. He may be a clever deviser of mechanisms, and an accurate predictor of what they will do, but completely ineffective as a member of a society that depends for its progress on the cooperation of educated men dealing with situations on which their personal specialties have little bearing.

The professional associations, or licensing bodies, have likewise an opportunity for significant and constructive action. Let them scrutinize with particular care the general educational qualifications of every applicant for admission, whether he comes by way of a university or directly from the shop, office, or field. Examinations for those who are not university graduates might very appropriately include a paper in English beyond the level of the last grade in high school.

Seasoned members of the profession should lose no opportunity of preaching sound professionalism in season and out. Its leaders should be invited to pass on to students the results of their experience and observation in functioning as responsible citizens and not merely as accomplished technolo-

gists. Young men in college will accept with avidity advice of this type "from outside" while they will listen incredulously to a member of the regular staff who tells them the same thing —and perhaps rather better.

The fullest possible use should be made of biographical material in attempting to press home concepts of desirable professional attitudes and conduct. After all, every one of us is much more interested in men and what they do than in philosophical or ethical doctrines.

College Notes

(*Continued from page 466*)

of current resources among the various departments of the College."

A $250,000 grant for atomic research and training of nuclear scientists has been made to the **Massachusetts Institute of Technology** by The Texas Company, according to an announcement today by Dr. Karl T. Compton, President of the Institute, and Col. Harry T. Klein, President of The Texas Company. The funds will be used for long-range pure research in nuclear fission and related basic studies on the ultimate nature of matter and energy, to construct high-voltage equipment of advanced design, and to train scientists in nuclear theory and its application. This work will be carried on primarily in the Laboratory for Nuclear Science and Engineering, which will coordinate its efforts with the departments of physics, chemistry, chemical, electrical and mechanical engineering, metallurgy, and biology, for maximum interchange of information.

Professor Norman Lincoln Towle, head of the Department of Electrical Engineering for the **Cooper Union School** of Engineering, will be acting dean of the School of Engineer, following the death of Dean George F. Bateman last Thursday, it was announced by Dr. Edwin S. Burdell, Director of The Cooper Union. Associate Professor William A. Vopat was named acting head of the Mechanical Engineering Department, a post which also had been occupied by Dean Bateman.

Professor Towle is senior member of Cooper Union's School of Engineering faculty, having been appointed instructor in electrical engineering in 1920. He has been Professor and head of the Electrical Engineering Department since 1932, and has done research in electrical engineering for the Bureau of Ships, United States Navy, and for Westinghouse Electric Co. He is a graduate of Worcester Polytechnic Institute.

Training in Manufacturing Processes*

By L. J. FLETCHER
Director of Training and Community Relations
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Education and training in manufacturing processes is becoming increasingly important. In the first place, increasing numbers of engineering graduates wish to enter production work in industry. This work requires detailed knowledge of manufacturing processes whereas entrance into the fields of research, design, sales, or service requires but a general knowledge of the subject. Secondly, there is an increasing demand from industry for production engineers. To meet this situation the engineering college is faced with a problem, one which cannot be solved by the introduction of one or more specialized courses. Let us first examine the problem, then suggest several solutions.

The term "manufacturing processes" is usually interpreted to mean such operations as casting, forging, rolling, welding, machining, inspection, and assembling. In industry, however, a general understanding of what takes place in each of these operations is insufficient, since cost is an all important factor in all competitive enterprises. In industry, these operations cannot merely be performed, they must be performed *economically*. Thus we introduce a new thought in the term "manufacturing processes," that of cost. Our definition might then be revised so that "manufacturing processes" includes those techniques necessary to produce parts and machines quickly, inexpensively, and uniformly with accurately controlled physical properties capable of easy assembly and replacement. The general public calls this *mass production.*

What is there about this idea of mass production that is so elusive? Even though these techniques and methods have been applied in the United States for many years, American engineers found little indication of their large scale application upon their inspection of German industry at the close of this last war. Is there any wonder then that colleges and universities meet a real challenge when asked to supply mass production specialists?

College Instruction

Let us examine the reasons why these techniques and ideas have been so difficult to teach exclusievly in the college classroom and laboratory.

First of all, there has been relatively little written on the subject of mass production. These techniques have been developed through the years primarily from the ingenuity and resource-

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fulness of skilled craftsmen employed in industry. The attitudes of these men were different from those of a professional engineer. They did not organize in societies and publish papers to inform their fellows of their new ideas. They were men who seldom wrote about their ideas or developments. Production changes took place so rapidly that it hardly seemed advisable to put material in text book form when it would likely be out of date by publication. When they developed a new process, these production men tended to keep it to themselves so that competitors could not immediately take advantage of their ideas.

Secondly, college laboratories are usually inadequate to demonstrate these production techniques. As long as industry used the basic tools such as drills, mills, and lathes, the college machine shop could afford to use them. But as time went on, mass production demanded more and more specialized tools. These tools varied widely even from one industry to another. The college laboratory could not economically keep up with this pace which has been accelerating rapidly since the close of the first World War.

True, college faculties include men skilled in mass production techniques. They have inaugurated excellent courses in time and motion study, plant layout, and manufacturing processes. However, they have been severely handicapped by lack of published material and insufficient laboratory equipment.

Industrial Training

To look at the other side of the picture for a moment, industries required an increasingly large number of production specialists as mass production industries expanded after the close of World War I. Since it was difficult up to fifteen to eighteen years ago to obtain engineers with the proper background and interests, many industries found the graduates of their apprentice and other training programs manning their mass production jobs. A predecessor of Caterpillar Tractor Co. commenced apprentice training in 1918. Training expanded and grew with the development and enlargement of the Company as the demand increased for production specialists. Today we at "Caterpillar" conduct, among other training activities, three four-year apprentice courses, four two-year programs, besides shorter courses in specialized production fields. Graduates of these courses have developed through the years and form the backbone of our factory production system.

As an illustration of this training in manufacturing processes, let us briefly describe our four-year Machinist Apprentice Course. It is typical of that found in many industries today.

The machinist apprentice, who is a selected high school graduate, first operates production machines on regular production assignments. His work is carefully chosen to give him a complete range of machine experience. Daily shop instruction by skilled trainers helps him to develop skills and techniques, and a complete acquaintance with the use of jigs and fixtures, close limits of work tolerance, and practical rates of production. After the machines in the production shop are mastered, he moves to the tool making division where increasingly difficult problems are encountered. Later in his program tool design, production planning, and other special training assignments give him the rounded out experience necessary in his specialty.

During this four-year period, the apprentice also receives over 600 hours of instruction in factory classrooms. The basic principles of many engineer-

ing subjects are covered. Theory as well as application is stressed.

Following are the subjects studied in 1947 by machinist apprentices in their classroom training at "Caterpillar":

Subject	Hours
1. Blueprint Reading and Shop Practice	40
2. Arithmetic, Algebra, and Geometry	48
3. Engineering Drawing	48
4. Applied Trigonometry	36
5. Arc Welding Procedure and Practice	24
6. Time and Motion Study	18
7. Industrial Physics	72
8. Manufacturing Processes	18
9. Effective Speaking and Composition	36
10. Gearing and Indexing	36
11. Heat Treatment and Metallurgy	48
12. Shop Layout, Routing, and Tooling	48
13. Tool Design	48
14. Industrial Economics	36
15. Hydraulics as Applied to Machine Tools	64
	620

Upon completing his course, the apprentice usually takes up work in tool making, production machining, or research machine shop.

There are also many so-called special courses to keep trained men up-to-date on the latest developments and to impart new knowledge to lesser skilled employees. We are now conducting a special 70-hour course in hydraulic controls of machine tools, with a combined laboratory and classroom type of meeting. Among those enrolled are machine repairmen with twenty-year service pins, as well as the recently graduated apprentices. Shortly after this course was inaugurated, the shop maintenance supervision requested another special course in electricity with emphasis on electrical controls for machine tools.

These skilled technicians in industry are continually studying the latest literature published on production techniques, they are meeting in their technical societies to hear experts on various topics pertaining to improved methods, and are each day giving of their talent to solve problems.

So industry attempts in part to fill its great demand by its own training of production specialists.

Engineering Graduates in Production

But engineers were still desired, so in 1931 we at "Caterpillar" started to recruit engineering graduates from the leading engineering colleges. By means of an orientation program, these young engineers became acquainted with our products through assembly line and proving ground assignments, and our engineering and research procedures by training in these departments. A few graduates at the outset were placed in our Manufacturing Department upon their expressed desire to do that type of work. However, we found the graduates of our four-year Machinist Apprentice Course, who had an excellent background in our machine shops, tool room, and tool design, outstripped these engineers on starting assignments.

Following is an illustraton of the problem encountered by engineering graduates. When beginning in manufacturing work in this Company, upon completion of College Graduate Training Course, the new man was usually assigned to the Timestudy Division. This work, as you know, consists of going into the shop and timing the series of operations of an employee on a production machine while he is producing a part. As you also know, it is necessary to have accurate timestudies which will be consistent from one operator to another and from one job to another.

Our engineering graduates, only generally familiar with machine shop procedures, who had not actually been in the

place of the operator they were timing, were unable to judge his skill and efficiency. It was difficult for them to analyze the correct feeds and speeds. They were uncertain how often tools should be sharpened or how long this should take. Furthermore, they had little idea of the time required to set up the machine. Operators would sometimes "slow down" while the time-study man was present, and some of these operators were rather skilled in misleading inexperienced men. Consequently, the machinist apprentice graduate proved superior to the graduate engineer on this first basic assignment because the apprentice had a first-hand knowledge of mass production machine operation.

It was recognized, however, that the college graduate had many qualifications which were most valuable. His better grasp of the fundamentals of physics and the application of natural laws allowed him, in general, to surpass the machinist graduate when it came to complex analysis.

Cooperative Plan

Our solution to this problem was the establishment in 1938 of a Cooperative Engineering Course. Here we hoped to combine the theoretical knowledge of the engineering graduate with the shop knowledge of the machinist. At first, the Cooperative Course was a direct combination of the two programs. Later on, cooperative training in the plant was changed and broadened to allow the trainee to have varied production experience with all types of manufacturing processes, such as machining, welding, casting, heat treatment, production assembly, and inspection. The stations were carefully chosen to obtain the maximum value from each experience. The trainee does not remain on each station a sufficient time to be a skilled craftsman but he encounters many representative problems peculiar to each type of work.

Thus we have an engineer with considerable first-hand experience with manufacturing processes. He not only knows what the processes are, but how they can be performed economically in a competitive business. Let us say he has absorbed the philosophy of mass production and is trained and equipped to aid in the development of better and less expensive methods of manufacturing our products.

It might be of interest to you to review figures which show a definite trend of graduates of certain above-mentioned courses toward production work.

Of 165 graduates of our College Graduate Orientation Course who are now with the Company, only nine or slightly over 5 per cent are working in the Manufacturing Department. On the other hand, of the 612 four-year machinist apprentices graduating since 1930 and now in our employ, 464 or 75 per cent are now engaged in the Manufacturing Department. Since 1943, there have been ten men graduate from our Cooperative Engineering Course. Seven of these are engaged directly with production problems dealing with manufacturing processes.

Effective training in manufacturing processes for engineers can result only through the joint action of the college and the industries it serves. The engineering college cannot isolate itself from industry in the teaching of this subject.

It is not intended here to outline specific courses, recommend the number of credit hours, or tell how courses in manufacturing processes should be taught. If the engineering faculty is

familiar with industry's problems, they can then adapt this knowledge in planning their curriculum.

We wish to emphasize the fact that we do not desire engineering colleges to turn out skilled machinists, coremakers, or arc welders. But the engineering graduate entering industry should have at least two qualifications if he expects to enter any of our production phases.

First of all, he should be familiar in general with the philosophy of mass production. He should have an appreciation of things that make up mass production, such as motion economy, timestudy, production standards and costs, and factory layout.

Secondly, he should be acquainted with the nomenclature and the basic practices of standard manufacturing processes such as casting, forging, rolling, machining, and welding. He should know the difference between spot welding and arc welding, the difference between the work done on a screw machine and an engine lathe, the place of permanent mold castings.

The cooperative system of engineering education is tailored to accomplish this result. Even though most schools are unable to schedule their classes for this rotating system, there are many compromises which may be developed.

College-Industry Relations

Engineering students interested in production work should be encouraged to work in industries during their summer vacations. They should be satisfied with a routine assignment, such as work on a production milling machine or on the molding floor of a foundry.

Factory trips have been used quite extensively in the past and since the close of the war period this program has been revived. Most industries welcome such inspection trips. If proper arrangements are made in advance, certain manufacturing processes may be covered in detail. For years at "Caterpillar," mimeographed sheets were furnished to each visiting engineering student describing certain manufacturing processes. The students studied these papers in advance, while in the factory they viewed the processes, and retained the descriptions for their future use. Often one part was followed through each operation until its assembly in the machine.

Where a close relationship exists between an industry and a college, qualified men from industry may from time to time explain to students the latest developments in manufacturing and describe the problems encountered. Industry has employed members of engineering faculties as consultants for many years and there is no reason why this procedure could not be reversed.

Many machine tool builders, steel companies, manufacturers of heat treating equipment, cleaning equipment, and chemical processing machinery, publish excellent descriptive booklets of their products and usually will put these into the hands of engineering students.

There are many other avenues of cooperation. By getting acquainted, the college faculties and executives of industry can work out many different systems for their mutual benefit.

It is thus evident that the problem of training engineers in manufacturing processes cannot be solved by the addition of new courses in an already overcrowded engineering curriculum. The solution likely will be found in the supplementing of the basic courses offered in the college classroom and laboratory with close first-hand knowledge of, and experience in, industry's methods and techniques.

A New Emphasis on Welding and Heat Treating for Mechanical and Industrial Engineers

By ROBERT S. GREEN

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As the first step in my discussion I should like to review for you the considerations we at Ohio State have made with respect to the general problem of shop work in the engineering curricula. Traditionally, in this and other institutions, courses in shop work have been originated and conducted by artisans, men who were highly skilled in their several trades. Their efforts have been for the most part directed principally at imparting a degree of their skill and experience to the student. This experience, if it could be efficiently dispensed, would be of great value to practicing engineers. That is, to explain further, if a mechanical or industrial engineer were a really skilled machinist, foundryman, pattern-maker, etc., he would have a truly exceptional starting place for the practice of engineering. It is obvious, of course, that thorough knowledge of these several branches would require a lifetime of preparation, leaving no time for practice in the engineering field. Can one short course with each of the skilled craftsmen provide the student with sufficient insight to the skill and experience which has been accumulated over the years by the mechanic? The consensus of opinion at Ohio State is that the student has not gained sufficiently in the time devoted to shop work, to justify the time thus spent. It is so easy to defend the teaching of skills in any one of the trades, and it has been done successfully in some of our major universities.

We are all cognizant of the heavy demand by industry and by men in all walks of professional life for amplified training in the humanistic and social arts and sciences. Most universities are taking steps to broaden the base of education for engineers in particular. At Ohio State this demand was the reason for adopting the five-year curricula in the Engineering College. Other universities are attempting to meet this demand within the scope of the four-year training program. This need for a widened scope of study is the driving force which is causing certain well-established courses in the technical field to be examined carefully as to their efficiency and necessity.

All of the work of the engineering shops was examined to determine whether the technical training obtained in them was of sufficient quality and quantity. The work done in the shops was found to be principally showing how to do forging, heat treating, welding, machining, and foundry work, without showing why the processes worked. A student was expected to

* Presented at the Joint Meeting of the Manufacturing Processes and Industrial Engineering Divisions of the A.S.E.E. in Minneapolis, June 18–21, 1947.

accomplish his given mechanical tasks as he was instructed without going much further. Grades depended upon the accuracy of his machining, and the strength of his welded specimens. We did not feel that our shops were accomplishing much in engineering training, and further, that during the short period of contact between the craftsman and the student, not a sufficient amount of skill and experience was obtained to affect any significant change in the subsequent professional status of the engineer. Consequently, the shops must be made to carry their full weight in engineering training or be discontinued in favor of other courses.

Of the two possible choices, Ohio State chose to retain the work of the shops, and to present the material from the engineering standpoint. It is felt that more can be taught concerning the materials, the machines, and the processes of modern industry in the shops than in other possible courses. There are in addition certain by-products derived from the shop program. The student learns to appreciate the work of the skilled mechanic in the industrial organization; the student gains some knowledge of shop procedure and basic safety precautions; the student gains in self-confidence; and last and in this case the least important, the student acquires some small manual skill. He is then left with a basis for future courses in safety, quality control, design, and management, and a corresponding advantage in his first positions of responsibility.

One question sometimes brought up is why there should be any discrepancy in the viewpoint of the mechanic and the engineer. The engineer is concerned with applying general physical laws to the solution of many types of problems and he must have an adequate grasp of such principles to be able to predict the outcome of a machine, structure, or set of conditions. The skilled mechanic throughout his years of experience has observed various physical phenomena for which he does not understand the principle but has learned to deal with by trial and error. Modern production in a competitive market cannot permit guesswork design, and our engineers must be able to use sufficient amounts of proper materials, without waste and excess cost. We all recognize some such distinction, and in our case it came to be a matter of putting these basic ideas in practice. The first step was the decision to obtain the services of practicing engineers for the direction and teaching of the shop courses. This does not mean that there is no place left in the program for the skilled craftsman. The mechanic is highly useful in the laboratory, and in demonstration work. The craftsman, however, must be led to realize that there is a necessary change from the vocational to the engineering teaching.

With this general discussion of overall aims I should like to turn to the solution of the problems in this particular area indicated by the title of this paper. The definite function of the course in Welding and Heat Treating is to illustrate the forming and treatment of metals for the tools of industry, and to provide the foundation for the use of the welding processes in the production and construction fields.

It is well to consider the place or necessity for this particular phase of the shop work. The necessity arises principally from the wide use of the welding techniques in industry, and the relatively small amount of education in this new field. Work in heat treatment is very widely used in in-

dustry, but there are two reasons for its inclusion. The first reason is to show the action of metals under heating, without which there can be no understanding of the welding processes, and secondly that the choice and conditioning of metals have large influence upon design work. Many persons regard the practice of welding as a new untested process which may come into general use sometime in the future. This point of view was out of date at least fifteen years ago, and with their many advantages and disadvantages, the welding processes have taken a predominant place in industry. Welding has already replaced established forms of fasteners in many phases of fabrication, and yet many of our technical institutions are content either to ignore or to sit on the sidelines and wait to be convinced.

The specific aims of our course in Welding and Heat Treating are to develop an understanding of the heating and cooling cycle in ferrous metals, to study metals from the physical standpoint, and to integrate the knowledge of the physical and metallurgical properties of metals, as a basis for comprehension of the welding process.

Ohio State operates on the quarter system and our mechanical and industrial engineering students have one three credit hour course in Welding and Heat Treating. This means that the student spends six hours a week in the course during the ten week quarter. From the first it was agreed that there should be no increase in the amount of time devoted to the course, inasmuch as our objective was merely to bring the work of the shops up to the level of the remainder of the college. The course is arranged so that there are two one-hour lectures each week, and two two-hour laboratory periods each week. At present we are in the midst of our changeover in course content in this area.

I should like to outline for you the lecture topics by weeks as they are planned for this summer quarter which is now in progress.

1st Week—The Physical Properties of Metals.—In this section such fundamental conceptions as total and unit stresses, elasticity, ductility, hardness and toughness are discussed.

2nd Week—The Properties of Carbon Steels.—The various structures of hardened, tempered, and annealed carbon steels are shown on slides, and use is made of the iron carbon diagram. The student is expected to recognize the more common structures of carbon steels.

3rd Week—The Properties of Alloy Steels.—The effects of the several groups of alloying elements are shown.

4th Week—Heat Treating and Forging Processes.—The direct application of heat treating to tool and product manufacture is discussed, and the flow of metals and grain refinement during forging are shown.

5th Week—Welding Processes.—Metallic arc and oxyacetylene welding are discussed in detail and reference is made to other phases such as resistance welding, methods involving inert gas shielding, and production equipment.

6th Week—Welded Joints.—Proper joint forms are shown and welding symbols are used to represent them. Bakelite models of joints are made and students are shown by photoelastic means the stress concentrations around discontinuities. Rubber models are pulled

in an opaque projector to illustrate the same ideas utilizing the greater deformation possible in this type of model.

7th Week—Welding Various Metals.—Discussion centers about the application of welding to high carbon and alloy steels, and effort is made to tie in previous discussions of heat treatment of similar materials.

8th Week—Weld Inspection.—Primary emphasis is placed upon visual inspection, with discussion of the several destructive and nondestructive tests. The qualification of operators for code work is surveyed.

9th Week—Stress Distribution.—The stresses set up by expansion and contraction and the residual stresses as influenced by the geometry of the weldments are considered.

10th Week—Welding Applications.—Discussions are held on the industrial applications in the fields of machine tools, piping, pressure vessels, automotive, aeronautical, and structural work.

The laboratory work is divided roughly into thirds. The first section is conducted in the heat treating shop where the student hardens and tempers samples of various carbon contents, hardness testing, microscopic examination, and machine forging demonstrations. The next section of the laboratory work is in oxyacetylene cutting and welding. The third section is devoted to metallic arc welding. During the latter two-thirds of the laboratory time the staff demonstrates such processes as atomic hydrogen, heliarc, metal spray, hard facing, flame hardening, automatic arc welding, and magnaflux inspection.

During this short time in the shops a large share of the students are able to weld tension specimens which will break the parent metal, both with the oxyacetylene and with the electric arc. The students have sufficient time in the shop to become well grounded in visual inspection, and are able to distinguish readily the signs of competent welding.

I have presented a rather detailed picture of our solution to the problem posed in one of our shops, with the idea in mind that it may be of interest to other universities in a similar state of flux.

It is my firm conviction that the engineering shops should and do have a vital place in the engineering curricula, and further, that they can be utilized to teach engineering in the best sense.

English is English

By FRED H. GERTZ

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In the September, 1947, issue of this JOURNAL, Professors Crouch and Zetler [1] accuse the typical department of English of being sadly deficient in its teaching of the embryonic engineer. As a remedy they propose either the creation of a separate department in the School of Engineering, or the forming of a separate division within the department to serve the students in engineering.

Perhaps our teaching of engineers has been deficient, but it seems that Crouch and Zetler are like the doctor who cures a hangnail by amputating the patient's hand. There is no good reason, educationally, for the creation of a separate division or department for engineers. If the engineer's education be narrow now, such a practice will make it even more restricted; for he would learn much from daily contact in class with students from other divisions of the college. It will do both the engineer and the liberal artsman a world of good to be thrown together in the same class. The artsman needs to know that there are those whose bent is to the practical, while the prospective engineer must learn, and quickly, that if life be not all beer and skittles, neither is it one long succession of generators, charts, graphs, and equations.

Even the aesthetic teacher, damned by "Dean Hobhouse," may be a healthy influence.[2] Perhaps the more bored he is, the better for the student. The prospective engineer should not expect to be cradled all through college thoroughly protected from the virus of aestheticism. The aesthete has a place in any department of English, and he should not be reserved for the liberal artsmen alone.

Then, too, there seems to be a general impression that the embryonic engineer is a dedicated soul—a creature set apart from his fellows. He is supposed to be a hard-headed, practical, feet-on-the-ground fellow, while others, especially liberal artsmen, are merely "ineffectual angels" beating their wings in an academic void. There is no reason why the engineer should not be called upon to exercise his imagination. Certainly the better engineers are those whose knowledge is not bounded by the practical. Many of the commonplace machines of today are the products of "impractical" engineers.

Perhaps a theme on the taste of celery would fail to arouse enthusiasm in the heart of the freshman engineer, but neither will the liberal artsman re-

[1] Crouch, George W., and Zetler, Robert L., "The Engineer Hates Grandfather's Horse." THE JOURNAL OF ENGINEERING EDUCATION, vol. 38, No. 1 (September, 1947), pp. 73–76.

[2] Cf. "Instruction in English in Engineering Education," *loc. cit.*, Supplement to vol. 30, No. 10, pp. 54–55.

spond joyfully. Granted you must start with what the student knows, but eventually you must broaden his interests so that the engineer will write about Shelley and the liberal artsman about an industrial incentive system. If the theme topics are unsatisfactory for engineers, they're unsatisfactory for all other students.

Certainly there is a need for advanced courses in technical writing devoted solely to the problems of the engineer, but why must the freshman course be adapted to engineers? Have not pre-medicals, pre-laws, pre-anything the same right to demand their own separate little courses in English? Are not the ideals of "engineering writing" the ideals of all good writing?

The solution lies not with any new system of organization, but with the teacher himself. If he's a poor teacher —and a man can teach as poorly in the School of Engineering as he can in the College of Liberal Arts—nothing can save him. The instructor needs to have sympathy and understanding. Suspect is that instructor who considers engineering students and engineering faculty not worthy of his time. He isn't an effective teacher of liberal artsmen either.

Field Determination of Latitude and Longitude in Advanced Surveying

By M. O. SCHMIDT

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Foreword.—In recent years considerable attention has been directed towards the problem of rapidly and economically providing control for mapping operations especially for those in sparsely-settled areas where little previous mapping or surveying had been done. This need became particularly acute during the war years and stimulated considerable research leading to the evolution of new methods or the improvement of older ones for making rapid determinations of astronomic position.

Generally speaking, few teachers of surveying are conversant with the methods of determining astronomic position and even with the conventional methods that have been used for many years by the U. S. Coast and Geodetic Survey. Hence, the purpose of this paper is to provide a brief introduction to a comparatively new and little known method for determining latitude and longitude and to report on the results of a recent field investigation that was made by the author in the summer of 1947 at Camp Rabideau, the new Survey Camp of the University of Illinois in northern Minnesota.

The "equal-altitude" method of position fixing is gaining wider acceptance among surveying and mapping organizations and is a peculiarly useful pedagogical method since it is not difficult to understand, requires no expensive equipment or special theodolite for results of moderate accuracy, and because of its close relation to the Summer Line of Position Method so familiar to our aerial and surface navigators of World War II, can serve as an excellent approach, in peacetime, to the subject of navigation.

Introduction

In August, 1943, while attending a session of the First Annual Seminar in Aerial Photogrammetry sponsored by Michigan State College and A.S.E.E. (then S.P.E.E.) at Lansing, Michigan, I had the opportunity to listen to a paper on "The Use of the Prismatic Astrolabe" by Major Weld Arnold of the Army Air Forces. To most of us the prismatic astrolabe was an entirely new surveying instrument although it had been satisfactorily used by the U. S. Navy Hydrographic office for astronomic position determinations since 1938 in Central and South America and earlier than this by the French. Considerable information regarding constant-altitude instruments such as the prismatic and the pendulum astrolabes can now be found in engineering literature. As yet they have not supplanted the conventional instruments used for position fixing except in a few cases where the greatest emphasis

has been upon speed even at the expense of reduced accuracy. Present developments, however, are such as to indicate quite definitely that the equal-altitude method will continue to gain the favor of engineers engaged in establishing horizontal control by astronomic means.

Theory

Let us imagine a transit with vertical axis truly vertical set up at any point on the earth's surface and with the telescope at some fixed angle such as 60 degrees with the horizontal. If the transit be rotated about its vertical axis the line of sight will describe a circle on the celestial sphere and the zenith of the observer will be at the center of the circle whose radius is equal to the fixed zenith distance of the instrument.

If the time of passage of several known stars over the almucantar be ascertained, it is therefore possible to locate the center of the fixed altitude circle and hence the point of observation.

Before beginning his observations the engineer determines from the best sources available to him the approximate latitude and longitude of the station to be occupied. He then estimates the range of time during which he plans to do the observing. With these data he refers to specially-prepared star lists arranged for a specific altitude such as 60 degrees and determines what stars will cross the fixed altitude circle of his instrument during that range of time. From the list he selects a number of stars and also extracts the azimuth and approximate local sidereal time of their crossing choosing stars so that several minutes will elapse between the crossing of successive stars. Then, in the fundamental PZS astronomical triangle concerned in the subsequent office computations, the known quantities are the assumed latitude, the star's declination, and the hour angle. The latter quantity is deduced from the assumed longitude, the observed Greenwich Sidereal Time at which the star crosses the almucantar, and the body's right ascension. From the law of cosines applied to a spherical triangle the expression for finding the zenith distance is derived. This equation is Cos. Z.D. = Cos. Lat. Cos. H.A. Cos. Dec. + Sin. Lat. Sin. Dec. It is therefore possible to compute the zenith distance of each star at the instant of observation. The difference between the calculated zenith distance and the observed zenith distance then is seen to be a measure of the inaccuracy in the original choice of the latitude and longitude values for the observation point.

If then on a sheet of special polar coordinate paper one takes the origin of coordinates as the assumed position of the observer and plots in the direction of the azimuth of each star the zenith intercept and erects a perpendicular segment thereto it is seen that these tangents, if well distributed in azimuth will define a circle whose center will represent the new position of the observation point. The distance from the origin of the plot to the center of the circle will then represent the corrections, in units of the graph, to the assumed latitude and longitude.

The basic concepts of this method are seen to be very analogous to the Summer Line of Position Method used for obtaining a navigational fix.

Instruments

The basic instruments used for most equal-altitude position observations are the prismatic astrolabe and the pendu-

lum astrolabe and their various modifications such as the Equi-angulater of the U. S. Army Air Forces.

Very briefly the prismatic astrolabe is an instrument which insures constancy of the altitude angle through the use of a 60 degree prism and a horizontal telescope which can be moved in azimuth only. This instrument is of French origin.

The pendulum astrolabe which is manufactured by the David White Company of Milwaukee, Wisconsin, consists of an 80-power telescope "split" so that the optical axes of the objective lens and the eye piece assembly lie in the same vertical plane and at an angle of 30 degrees from the vertical axis, but on opposite sides of the latter. A centrally-located surface mirror which is mounted horizontally on an air-dampened pendulum serves to reflect the rays from the star to the eye of the observer.

While the true zenith distance of a star observed with a constant-altitude instrument will not be obtainable because of uncertainties in refraction and mechanical imperfections in the instrument, all stars will be observed at sensibly the same zenith distance provided the duration of the observation program is not too great to permit significant changes in refraction, and hence, no measure of inaccuracy will be introduced. It is only materially important that the observed zenith distance remain constant. It need not be exactly 30° or some other selected angle.

Field Investigation at Camp Rabideau

In general, the equal-altitude method is used only when an astrolabe is available. To investigate the possibilities of employing an ordinary theodolite with an angle of 60 degrees set on the vertical arc the author conducted a brief program of observations in August, 1947, utilizing the principle of equal altitudes. The results obtained were then compared with those ascertained by geodetic traverse from a point of known geodetic position in the town of Blackduck, Minnesota to the astronomical observation point in Camp Rabideau which is situated about six miles due south of Blackduck. The results obtained in this field investigation point out the general usefulness of this method even if only an ordinary transit is available provided a good chronometer and a short-wave radio set for time control is available.

Astronomic observations were made on the evenings of August 29 and August 30, 1947, with a Berger theodolite. Using the scaled values of the latitude and longitude, viz., Latitude 47°–38′–30″ and Longitude 94°–33′–05″, a star observation list had been previously prepared with the aid of Arnold's "Complete Sixty-degree Star Lists for Position Fixing by the Equal-Altitude Method." The observer's pocket watch was set to local sidereal time and just before setting up over the observation point the time error to the nearest one-tenth of a second of the chronometer was determined by radio time signals from Station WWV, National Bureau of Standards, Washington, D. C.

Several minutes prior to the estimated time of passage of a star over the 60-degree almucantar the telescope was pointed in the known direction of the star, the control bubble on the vertical arc was carefully centered, and a vertical angle of 60 degrees set off. Then, as the star came into the field of view an attempt was made to change slightly the azimuth setting so as to

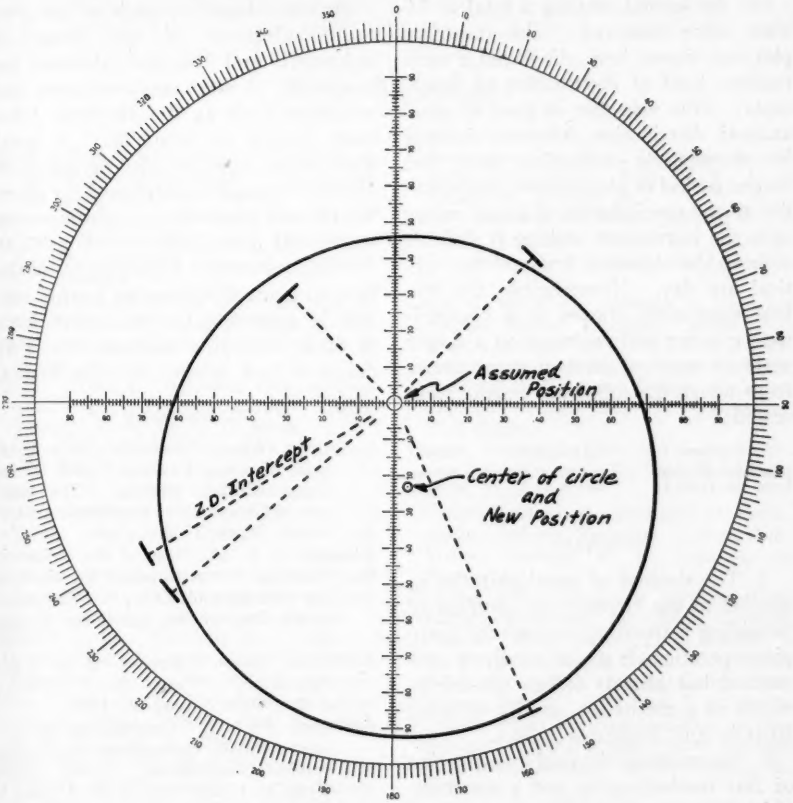

FIGURE 1

cause the star to cross the horizontal wire at or very close to the vertical wire. At the precise moment of crossing the horizontal wire, a stop watch was started and as soon thereafter as possible was stopped on an observed reading of the chronometer. The Central Standard Time of the star's passage was then obtained by subtracting the stop watch interval from the corrected chronometer time. A prismatic eye piece was required, of course, to view all stars. It was found that this attachment is not too easy to use at night. A plot of the results of this preliminary observation on August 29 is to be seen in Fig. 1. If the results obtained by traverse are assumed as correct the position coordinates obtained by observation are surprisingly close. The two sets of coordinate values compare as follows:

	Traverse	Astronomic	Error
Lat.	47°-38′-26.06″	47°-38′-24.7″	−1.4 sec.
Long.	94 -33 -04.49	94 -33 -03.6	−0.9 sec.

On the second evening a total of 14 stars were observed. The resulting plot, not shown here, displayed a very random kind of distribution of intercepts. This was due in part to poor azimuth distribution, inherent changes in atmospheric refraction over the longer period of observation, and error due to the precipitation of heavy vapor over the instrument making it difficult to keep the objective lens and the vertical arc dry. Nevertheless, the five best stars were chosen in a discriminate manner and replotted to a larger scale on another sheet of graph paper from which the following results were scaled:

	Traverse	Astronomic	Error
Lat.	47°-38'-26.06"	47°-38'-25.6"	−0.5 sec.
Long.	94 -33 -04.49	94 -33 -05.2	+0.7 sec.

Summary

1. The method of equal-altitudes as applied to the engineering problem of providing astronomic control for mapping operations is a comparatively new method but already it has proved its worth as a means for rapidly securing latitude and longitude values.

2. The results of the field investigation of this method using not a constant-altitude instrument such as an astrolabe but an ordinary theodolite with its telescope set at a fixed vertical angle indicates that the results obtained should be correct within a few seconds of latitude and longitude.

3. An introduction to the method of equal altitudes for the advanced surveying student is a desirable supplement to the content of the usual course for it affords an opportunity for the student to gain an acquaintanceship with a means with which he can find, without expensive equipment and with moderate accuracy, his mapping position on the earth.

Mention should be made of the general inadequacy of the American Ephemeris and Nautical Almanac for this work. A more comprehensive star catalogue such as the Berliner Jahrbuch should be available. A good short-wave radio set such as the S–38 Hallicrafter can be purchased for about $50.00 and a satisfactory chronometer watch with a small rate for about $100.

A representative bibliography of the more important references to this subject is appended for the convenience of those surveying teachers who may desire to look farther into the matter.

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